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Docket No. 34013-28PT

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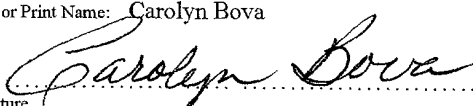
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re patent application of: Gregory G. Cappiello, Robert H. Dueck, and Mikhail N. Sokolskiy

For: DIFFRACTION GRATING FOR WAVELENGTH DIVISION  
MULTIPLEXING/DEMULTIPLEXING DEVICES

BOX PATENT APPLICATION  
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Washington, D.C. 20231

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PATENT APPLICATION TRANSMITTAL LETTER

Transmitted herewith for filing, please find the following:

- X Specification, claims and abstract of the above-referenced patent application (total of 105 pages)
- X 12 sheet(s) of drawing(s) (\_\_\_ formal/ x informal).
- X Combined Declaration and Power of Attorney (unexecuted).
- \_\_\_ An Assignment of the invention to: \_
- X Small entity status is claimed under 37 CFR 1.9 and 1.27.
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- \_\_\_ This application is a:

- \_\_\_ Continuation
- \_\_\_ Divisional

Continuation-In-Part

of prior copending parent application Serial No. filed on \_\_\_now pending.

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--This application is a Continuation of prior application Serial No. \_\_\_\_\_ filed on \_\_\_\_\_, now pending.--

In the event that a petition to extend time under 37 CFR 1.136 is necessary in the parent application to maintain copendency for this application, a petition for an extension of the necessary time to maintain copendency is hereby requested for the parent application and the Commissioner is hereby authorized to debit our Account Number 10-0447 for the necessary fees.

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INDEPENDENT CLAIMS	19- 3	16	\$80	\$1,280
MULTIPLE DEPENDENT CLAIM(S) PRESENTED			\$260	
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- [illegible]

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DIFFRACTION GRATING FOR WAVELENGTH DIVISION

MULTIPLEXING/DEMULTIPLEXING DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application is related to and claims priority from U.S. Patent Application No. 60/208,478, filed June 2, 2000 (Attorney Docket No. 34013-28USPL); U.S. Patent Application 60/208,482, filed June 2, 2000 (Attorney Docket No. 34013-27USPL); U.S. Patent Application 60/208,477, filed June 2, 2000 (Attorney Docket No. 34013-33USPL); and U.S. Patent Application 60/208,483, filed June 2, 2000 (Attorney Docket No. 34013-29USPL). This

application is also related to U.S. Patent Application No.  
09/382,492 (Attorney Docket No. 34013-00013), filed August 25,  
1999; U.S. Patent Application No. 09,545,826 (Attorney Docket No.  
34013-17), filed April 10, 2000; U.S. Patent Application No. \_\_\_\_\_,  
5 filed June 2, 2000, entitled "ATHERMALIZATION AND PRESSURE  
DESENSITIZATION OF DIFFRACTION GRATING BASED WDM DEVICES"  
(Attorney Docket No. 34013-27USPT); U.S. Patent Application No.  
\_\_\_\_\_, filed June 2, 2000, entitled "ATHERMALIZATION AND PRESSURE  
DESENSITIZATION OF DIFFRACTION GRATING BASED WDM DEVICES"  
10 (Attorney Docket No. 34013-48USPT); U.S. Patent Application No.  
\_\_\_\_\_, filed June 2, 2000, entitled "ATHERMALIZATION AND PRESSURE  
DESENSITIZATION OF DIFFRACTION GRATING BASED SPECTROMETER DEVICES"  
(Attorney Docket No. 34013-33USPT); U.S. Patent Application No.  
\_\_\_\_\_, filed June 2, 2000, entitled "ATHERMALIZATION AND PRESSURE  
15 DESENSITIZATION OF DIFFRACTION GRATING BASED SPECTROMETER DEVICES"  
(Attorney Docket No. 34013-47USPT); U.S. Patent Application No.  
\_\_\_\_\_, filed June 2, 2000, entitled "OPTICAL PERFORMANCE MONITOR  
WITH OPTIMIZED FOCUS SPOT SIZE", (Attorney Docket No. 34013-  
29USPT); and U.S. Patent Application No. \_\_\_\_\_, filed June 2, 2000,  
20 entitled "DEVICE AND METHOD FOR OPTICAL PERFORMANCE MONITORING IN

AN OPTICAL COMMUNICATIONS NETWORK", (Attorney Docket No. 34013-40USPT). The above-listed applications are hereby incorporated by reference in their entirety.

5       **FIELD OF THE INVENTION**

10       The present invention relates generally to wavelength division multiplexing and, more particularly, to a diffraction grating for relatively high efficiency wavelength division multiplexing/demultiplexing devices.

15       **BACKGROUND OF THE INVENTION**

20       Optical communication technology relies on wavelength division multiplexing (WDM) to provide increased bandwidth over existing installed fiber optic lines, as well as newly deployed fiber optic line installations. Several technologies exist to provide the technical solution to WDM: array waveguide gratings (AWG's), fiber Bragg grating based systems, interference filter based systems, Mach-Zehnder interferometric based systems, and diffraction grating based systems, to name a few. Each system has advantages and disadvantages over the others.

Diffraction grating based systems have the advantage of parallelism, which yields higher performance and lower cost for high channel count systems. In particular, a diffraction grating is a device that diffracts light by an amount varying according to its wavelength. For example, if sunlight falls on a diffraction grating at the correct angle, the sunlight is broken up into its individual component colors (i.e., rainbow).

Gratings work in both transmission (where light passes through a material with a grating written on its surface) and in reflection (where light is reflected from a material with a grating written on its surface). In optical communications, reflective gratings have a widespread use. A reflective diffraction grating includes a very closely spaced set of parallel lines or grooves made in a mirror surface of a solid material. A grating can be formed in most materials wherein the optical properties thereof are varied in a regular way, having a period that is relatively close to the wavelength. Incident light rays are reflected from different lines or grooves in the grating. Interference effects prevent reflections that are not in-phase with each other from propagating.

There are two primary groove profiles in conventional diffraction gratings, blazed gratings and sinusoidal gratings. The blazed grating includes a jagged or sawtooth shaped profile. The sinusoidal grating has a sinusoidal profile along the surface of the grating.

The diffraction equation for a grating is generally described by

$$Gm\lambda = n(\sin(\alpha) + \sin(\beta))$$

where,  $G=1/d$  is the groove frequency in grooves per millimeter and  $d$  is the distance between adjacent grooves,  $m$  is the diffraction order,  $\lambda$  is the wavelength of light in millimeters,  $\alpha$  is the incident angle with respect to the grating normal,  $\beta$  is the exiting angle with respect to the grating normal, and  $n$  is the refractive index of the medium above the grooves.

Figure 12A is a representative pictorial showing optical characteristics of a blazed diffraction grating in reflecting a narrowband optical signal. The blaze diffraction grating 900 is defined by certain physical parameters that effect optical performance. These physical parameters include the reflection surface material, the number of grooves  $g$  per millimeter, blaze



angle  $\theta_B$ , and the index of refraction of an immersed grating medium 902. The reflection surface 905 typically resides on a substrate 910.

As shown on FIGURE 12A, the groove spacing is defined by  $d$ .  
An incident narrowband optical signal with a center wavelength  $\lambda_1$  has an incident angle  $\alpha_1$  (measured from the grating normal  $N_g$ ) and a reflection angle  $\beta_1$  (also measured from the grating normal  $N_g$ ). The angle between the grating normal  $N_g$  and the facet normal  $N_f$  defines the blaze angle  $\theta_B$ .

As previously discussed, when narrowband light is incident on a grating surface, it is diffracted in discrete directions. The light diffracted from each groove of the grating combines to form a diffracted wavefront. There exists a unique set of discrete or distinct angles based upon a given spacing between grooves that the diffracted light from each facet is in phase with the diffracted light from any other facet. At these discrete angles, the in-phase diffracted light combine constructively to form the reflected narrowband light signal.

A sinusoidal diffraction grating is similarly described by the equation above. When  $\alpha=\beta$ , the reflected light is diffracted

directly back toward the direction from which the incident light was received. This is known as the Littrow condition. At the Littrow condition, the diffraction grating equation becomes

$$m\lambda = 2d n \sin(\alpha),$$

where  $n$  is the index of refraction of the immersed grating medium 902 in which the diffraction grating is immersed.

Figure 12B is a representative pictorial showing optical characteristics of a sinusoidal diffraction grating. Sinusoidal gratings, however, do not have a blaze angle parameter, but rather have groove depth ( $d$ ). An immersed grating medium 955 resides on the sinusoidal grating 950 having a certain index of refraction,  $n$ . The diffraction grating equation discussed above describes the optical characteristics of the sinusoidal diffraction grating based upon the physical characteristics thereof.

Figure 12c shows a polychromatic light ray being diffracted from a blazed grating 960. An incident ray (at an incident angle  $\theta_i$  to the normal) is projected onto the blazed grating 960. A number of reflected and refracted rays are produced corresponding to different diffraction orders (values of  $m=0, 1, 2, 3, \dots$ ). The reflected rays corresponding to the diffraction order having the

highest efficiency (i.e., lowest loss) are utilized in optical systems.

5 As with most communications systems, there is a need to provide improved optical transmission rate and more efficient propagation of the communication signals in the fiber optic communication system. By improving the efficiency and/or decreasing the loss of the communication signals, the need to install optical repeaters and/or optical amplifiers is reduced, thereby decreasing operating costs of the system. Furthermore, an increase in signal efficiency reduces demand on fiber optic lines in a system, thereby reducing the need for burying additional optic lines. The burying of additional fiber optic cable is quite costly as it is presently on the order of \$15,000 to \$40,000 per kilometer.

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15 Because WDM devices generate optical signals, one area of improvement is focused on the insensitivity to signal polarization. As is well known, the polarization of a signal affects the speed at which pulse energy in the signal's polarization modes or states propagate in an optical fiber. As

a result, polarized signals generally cause significant timing and signal reconstruction problems within an optical system.

Ultimately, signal performance within a WDM device is attributable to a great extent to the performance of the diffraction grating therein. Because the parameter values which describe the diffraction grating often dictate the efficiency and the polarization effects of diffracted optical signals, much time, money, and effort have been dedicated to determining diffraction grating parameter values to effectuate improved transmission performance. Due in part to the number of diffraction grating parameters, the considerable range of corresponding parameter values, and the interdependencies between the diffraction grating parameters, designing and implementing a diffraction grating yielding improved performance are nontrivial.

In this regard, designing diffraction gratings must additionally take into account real-world effects that can only be measured empirically to determine if the theoretical parameters for a diffraction grating yield a viable solution. For example, one difficulty in creating improved diffraction gratings is the prolonged time period for creating a master diffraction grating.

5 A single diffraction grating master may take several weeks to  
produce. Although the master diffraction grating, having a  
specific set of grating parameters, may yield acceptable results  
(i.e., low loss or a partially polarization insensitive result),  
10 a replicated diffraction grating created from the master  
diffraction grating may produce less than desirable signal  
performance characteristics. Consequently, the process of  
designing and developing diffraction gratings (determining grating  
parameters that yield good signal and/or master grating related  
characteristics, producing a master diffraction grating having the  
determined grating parameters and producing a replicated  
diffraction grating from the master diffraction grating that  
yields good signal performance characteristics) so as to produce  
a diffraction grating having improved performance requires solving  
15 both theoretical and practical problems.

Based upon the foregoing, there is a need for a diffraction  
grating for employment within an optical system having improved  
signal performance.

20 **BRIEF DESCRIPTION OF THE DRAWINGS**

A more complete understanding of the system and method of the present invention may be obtained by reference to the following Detailed Description when taken in conjunction with the accompanying Drawings wherein:

5           Figures 1A and 1B illustrate diffraction grating profiles according to various embodiments of the present invention;

          Figures 2-7 are graphs showing the efficiencies of the various diffraction gratings according to embodiments of the present invention;

10           Figure 8 is a side elevational view of a wave division multiplexing/demultiplexing device according to an embodiment of the present invention;

          Figure 9A is a perspective view of a portion of the wave division multiplexing/demultiplexing device of Figure 8;

15           Figure 9B is an end view of the portion of the wave division multiplexing/demultiplexing device of Figure 8;

          Figures 10A-10D illustrate multiplexing and demultiplexing functions of the wave division multiplexing/demultiplexing device of Figure 8;

Figure 11 is a block diagram of an optical communications system according to an embodiment of the present invention; and

Figures 12A-12C illustrate the general concepts relating to diffraction gratings.

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#### **DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS**

The present invention will now be described more fully hereinafter with reference to the accompanying drawings in which a preferred embodiment of the invention is shown.

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Optical networks are utilized to handle telecommunications traffic caused in part by the Internet, mobile communications, and facsimile communications. To increase the bandwidth of optical networks, polychromatic fiber optic lines and/or carriers have been developed to allow for multiple signals to be carried by a single fiber optic line. A central component utilized in fiber optic communication is a wavelength division multiplexer/demultiplexer (WDM). WDM devices transmit polychromatic optical signals into and receive polychromatic optical signals from polychromatic fiber optic lines. Within the WDM, a diffraction grating is utilized to join a multiple number

of narrowband optical signals into a polychromatic optical signal in the multiplexing case, and separate a polychromatic optical signal into a multiple number of narrowband optical signals in the demultiplexing case. So that the WDM provides for high efficiency, embodiments of the present invention include a diffraction grating that is polarization insensitive.

In practice, narrowband optical signals or beams are not truly monochromatic, but rather a tight range of wavelengths. Each signal is defined by a narrow passband and has a center wavelength which is the representative wavelength to which an optical signal is associated. Each center wavelength is generally predefined, and may correspond with an industry standard, such as the standards set by the International Telecommunication Union.

An optics device may be described as being "polarization insensitive" if the power levels of the polarization states of one or more optical signals emitted from the device is the same as the power levels of polarization states of corresponding optical input signal(s) to the device. In other words, the device provides equal efficiency for both of the polarization states of the output optical signal(s) emitted from the device. Relatedly, a device



is "substantially polarization insensitive" if the power levels of the polarization states of output optical signal(s) emitted from the device are within approximately 20% of the power levels of the corresponding polarization states of input optical signal(s) to the device.

Further, the term "apolarized" is used below in describing the various embodiments of the present invention as meaning a signal condition in which the power of the transverse electric polarization state TE is equal to the power of the transverse magnetic polarization state TM at a pertinent wavelength or set of wavelengths. The term "substantially apolarized" is used below as referring to a signal condition in which the power of the transverse electric polarization state TE and the power of the transverse magnetic polarization state TM are within about 20% of each other at a pertinent wavelength or set of wavelengths. The term "efficiency" used below refers to a characteristic of an optical device. In particular, "efficiency" is used to mean the gain/loss of an optical signal or signal component generated from the optical device, relative to an optical signal received thereat. Relatedly, "polarization dependent loss" or "PDL" refers

to a characteristic of an optical device, and is used below to mean the maximum deviation in gain/loss across all input polarization states.

Referring to Figures 1A and 1B, there is shown a diffraction grating 1 according to embodiments of the present invention. Diffraction grating 1 is utilized in performing wavelength division multiplexing and demultiplexing operations, as described in greater detail below. Diffraction grating 1 may be a reflective grating so that optical and/or light rays are reflected or diffracted therefrom. Diffraction grating 1 may include a substrate 2 over which the diffractive surface of diffraction grating 1 is formed. Substrate 2 may be constructed from a number of different substances. For example, substrate 2 may be a glass compound. As shown in Figures 1A and 1B, substrate 2 may have a substantially planar shape. It is understood, however, that substrate 2 may alternatively include a substantially curved or concave surface (not shown) over which a diffraction grating surface is formed.

Diffraction grating 1 may further include a grating layer 3 which is formed over and/or bonded to a surface of substrate 2.

5 An exposed surface of grating layer 3 may have a grating profile.  
The grating profile of grating layer 3 may be formed a number of  
different ways, including the utilization of ruling or holographic  
techniques, as is known in the art. The particular grating  
profiles and corresponding characteristics of grating layer 3  
according to the embodiments of the present invention will be  
described in greater detail below.

10 A reflective layer 4 is formed over and/or bonded to the  
exposed surface of grating layer 3. Reflective layer 4  
substantially forms the particular grating profile of grating  
layer 3. Reflective layer 4 may be a metal composition, such as  
gold, aluminum or silver.

15 An optically transmissive material or coating 5 may be  
disposed over or adjacent reflective layer 4. Material 5 is  
utilized to increase the reflectivity of diffraction grating 1.  
Material 5 is shown in Figure 1A as being formed directly over  
reflective material 4. It is understood, however, that an  
additional layer (not shown), such as a bonding agent having a  
different index of refraction relative to material 5, may be  
20 disposed between material 5 and reflective layer 4.

It is understood that diffraction grating 1 may include additional or fewer layers than described above. For example, a surface of substrate 2 may be worked so as to form a grating profile thereon, and reflective layer 4 bonded to or formed directly on substrate 2. Alternatively, a thickness of reflective layer 4 may be sufficiently dimensioned so that a surface of reflective layer 4 may be worked to form a grating profile thereon, thereby rendering substrate 2 and grating layer 3 unnecessary. Diffraction grating 1, however, will be presented as a three layer diffraction grating for exemplary purposes.

In accordance with the embodiments of the present invention, the grating profile of diffraction grating 1 is characterized to provide enhanced optical communication. The enhanced optical communication performance of diffraction grating 1 is based upon a certain combination of parameters which define the grating profile of diffraction grating 1. As shown in Figure 1A and in accordance with an embodiment "A" of the present invention, diffraction grating 1 is a blazed grating type. The blaze angle of diffraction grating 1 is between about twenty-seven (27) and about thirty-nine (39) degrees. The number of grooves g per

millimeter of diffraction grating 1 may be generally defined by the equation

$$(500 \pm 110) * n,$$

where n is the index of refraction of material 5. The number of grooves per millimeter may be more particularly defined between: about 700 and about 800 when the index of refraction n of material 5 is between about 1.44 and about 1.64 and the blaze angle is between about 27 and 32 degrees; between about 850 and 950 when the index of refraction n of material 5 is between about 1.44 and about 1.64 and the blaze angle is between about 31 and 34 degrees; and between about 950 and 1050 when the index of refraction n of material 5 is between about 1.44 and about 1.64 and the blaze angle is between about 34 and 39 degrees. In addition, the diffraction order utilized with embodiment A of diffraction grating 1 is the first order. The particular parameter values for embodiment A of diffraction 10 are summarized below in the following Table.

**TABLE - DIFFRACTION GRATING PARAMETERS**

	Grating Type	Reflection Surface	Grooves per Millimeter	Groove Depth (nm)	Index of refraction of immersed grating medium (typical)	blaze angle (deg)	diff. order
A	blazed	aluminum or gold	750±50 900±50 1000±50 (500±110)n	-	1.44 - 1.64 1.44 - 1.64 1.44 - 1.64	27 - 32 31 - 34 34 - 39	1
B	sinusoidal	aluminum or gold	750±50 (500±110)n	420 - 470 (685±40)/n	1.44 - 1.64	-	1
C	blazed	aluminum or gold	300±40 (200±40)n	-	1.44 - 1.64	37 - 40	4
D	blazed	aluminum or gold	600±40 (450±40)n	-	1.44 - 1.64	41 - 44	2
E	blazed	aluminum or gold	200±20 (200±20)n	-	1.0 (air)	68 - 76	5
F	blazed	aluminum or gold	250±30 (250±30)n	-	1.0 (air)	50 - 56	4

Figure 2 illustrates the resulting performance of embodiment A of diffraction grating 1 having the grating parameter values described above, based upon receiving an apolarized optical signal as an input. As can be seen, the efficiency of both the transverse electric polarization state TE and the transverse magnetic polarization state TM exceed 80% (the PDL being as low as 0.25dB) over both the C-band and L-band wavelength ranges.

Further, because the efficiencies of transverse electric polarization state TE and transverse magnetic polarization state TM are substantially the same across the C-band wavelength range and the L-band wavelength range, diffraction grating 1 diffracts substantially apolarized optic rays in response to the apolarized input optical signal. Consequently, diffraction grating 1 is substantially polarization insensitive across the C-band wavelength range (about 1520nm to about 1566nm) and the L-band wavelength range (about 1560nm to about 1610nm).

Still further, the cross-over point for the efficiency of the transverse electric polarization state TE and the efficiency of the transverse magnetic polarization state TM occurs in the C-band wavelength range, and particularly in the upper half thereof. The high efficiency combined with the location of the efficiency cross-over location result in diffraction grating 1 providing enhanced optical performance in both the C-band and L-band wavelength ranges.

In accordance with another embodiment of the present diffraction grating invention, Figure 1B shows the profile of embodiment "B" of a diffraction grating 1 of the sinusoidal

grating type. The groove depth  $d$  of diffraction grating 1 of embodiment B may be generally defined by the equation

$$(685 \pm 40)/n,$$

where  $n$  is the index of refraction of material 5. The groove depth may be more particularly defined between about 420nm and about 470nm when material 5 has an index of refraction between about 1.44 and about 1.64. The number of grooves  $g$  per millimeter of diffraction grating 1 may be generally defined by the equation

$$(500 \pm 110) * n,$$

and more particularly defined between about 700 and about 800 when material 5 has an index of refraction between about 1.44 and about 1.64. In addition, the diffraction order utilized with embodiment B of diffraction grating 1 is the first order. The particular parameter values for embodiment B of diffraction 10 are summarized in the Table.

Figure 3 illustrates the resulting performance of embodiment B of diffraction grating 1 having the grating parameter values described above, based upon receiving an apolarized optical signal as an input. As can be seen, the efficiency of both the transverse electric polarization state TE and the transverse



5 magnetic polarization state TM exceed 80% over the C-band and L-band wavelength ranges. Further, because the efficiencies of transverse electric polarization state TE and transverse magnetic polarization state TM are substantially the same and/or closely follow each other across the C-band and L-band wavelength ranges, diffraction grating 1 diffracts substantially apolarized optic rays in response to the apolarized input optical signal. Consequently, diffraction grating 1 is substantially polarization insensitive across the C-band and L-band wavelength ranges.

10 Still further, the cross-over point for the efficiency of the transverse electric polarization state TE and the efficiency of the transverse magnetic polarization state TM occurs in the C-band wavelength range, and particularly in the upper end thereof. The high efficiency combined with the location of the efficiency cross-over point result in diffraction grating 1 providing enhanced optical performance in both the C-band wavelength range and the L-band wavelength ranges.

15 In accordance with another embodiment of the present diffraction grating invention, Figure 1A illustrates the profile of embodiment "C" of a diffraction grating 1 of the blazed grating

type. The blaze angle of diffraction grating 1 is between about thirty-seven (37) and about forty (40) degrees. The number of grooves G per millimeter of diffraction grating 1 may be generally defined by the equation

$$(200 \pm 40) * n,$$

where n is the index of refraction of material 5. More specifically, the number of grooves may be between about 260 and about 340 when material 5 has an index of refraction n between about 1.44 and about 1.64. In addition, the diffraction order utilized with embodiment C of diffraction grating 1 is the fourth order. The particular parameter values for embodiment C of diffraction 10 are summarized the Table.

Figure 4 illustrates the resulting performance of embodiment C of diffraction grating 1 having the grating parameter values described above, based upon receiving an apolarized optical signal as an input. As can be seen, the efficiency of both the transverse electric polarization state TE and the transverse magnetic polarization state TM exceed 60% over the C-band wavelength range. Further, because the efficiencies of transverse electric polarization state TE and transverse magnetic

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where  $n$  is the index of refraction of material 5. More specifically, the number of grooves may be between about 560 and about 640 when material 5 has an index of refraction  $n$  between about 1.44 and about 1.64. In addition, the diffraction order utilized with embodiment D of diffraction grating 1 is the second order. The particular parameter values for embodiment D of diffraction 10 are summarized in the Table.

Figure 5 illustrates the resulting performance of embodiment D of diffraction grating 1 having the grating parameter values described above, based upon receiving an apolarized optical signal as an input. As can be seen, the efficiency of both the transverse electric polarization state TE and the transverse magnetic polarization state TM exceed 70% over the C-band wavelength range. Further, because the efficiencies of transverse electric polarization state TE and transverse magnetic polarization state TM somewhat closely follow each other across the C-band wavelength range embodiment D of diffraction grating 1 diffracts substantially apolarized optic rays in the C-band wavelength range in response to the apolarized input optical signal.

In accordance with another embodiment of the present diffraction grating invention, Figure 3A shows the profile of embodiment "E" of a diffraction grating 1 of the blazed grating type. The blaze angle of embodiment E of diffraction grating 1 is between about sixty-eight (68) and about seventy-six (76) degrees. The number of grooves G per millimeter of embodiment E of diffraction grating 1 may be generally defined by the equation

$$(200 \pm 20) * n,$$

where n is the index of refraction of material 5. More specifically, the number of grooves may be between about 180 and about 220 when material 5 is air or otherwise has an index of refraction of about 1.0. In addition, the diffraction order utilized with embodiment E of diffraction grating 1 is the fifth order. The particular parameters for embodiment E of diffraction 10 are summarized in the Table.

Figure 6 illustrates the resulting performance of embodiment E of diffraction grating 1 having the grating parameter values described above, based upon receiving an apolarized optical signal as an input. As can be seen, the efficiency of both the transverse electric polarization state TE and the transverse

5 magnetic polarization state TM exceed 70% over the C-band  
wavelength range, and exceed 60% over the L-band wavelength range.  
Further, because the efficiencies of transverse electric  
polarization state TE and transverse magnetic polarization state  
10 TM somewhat closely follow each other across the C-band and L-band  
wavelength ranges, embodiment E of diffraction grating 1 diffracts  
substantially apolarized optic rays across the C-band and L-band  
wavelength ranges in response to the apolarized input optical  
signal. Still further, the cross-over point for the efficiency  
of the transverse electric polarization state TE and the  
efficiency of the transverse magnetic polarization state TM occurs  
in the C-band wavelength range, and particularly around the  
midpoint thereof. The high efficiency combined with the location  
of the efficiency cross-over point result in embodiment E of  
15 diffraction grating 1 providing enhanced optical performance in  
both the C-band wavelength range and the L-band wavelength range.

In accordance with another embodiment of the present  
diffraction grating invention, Figure 3A shows the profile of  
embodiment "F" of a diffraction grating 1 of the blazed grating  
20 type. The blaze angle of embodiment F of diffraction grating 1

is between about fifty (50) and about fifty-six (56) degrees. The number of grooves G per millimeter of embodiment F of diffraction grating 1 may be generally defined by the equation

$$(250 \pm 30) * n,$$

5 where n is the index of refraction of material 5. More specifically, the number of grooves may be between about 220 and about 280 when material 5 is air or otherwise has an index of refraction of about 1.0. In addition, the diffraction order utilized with embodiment E of diffraction grating 1 is the fourth order. The particular parameters for embodiment E of diffraction 10 are summarized in the Table.

Figure 7 illustrates the resulting performance of embodiment F of diffraction grating 1 having the grating parameter values described above, based upon receiving an apolarized optical signal as an input. As can be seen, the efficiency of both the 15 transverse electric polarization state TE and the transverse magnetic polarization state TM exceed 60% over the C-band wavelength range. Further, because the efficiencies of transverse electric polarization state TE and transverse magnetic polarization state TM somewhat closely follow each other across 20

the C-band wavelength range, embodiment F of diffraction grating 1 diffracts substantially apolarized optic rays in response to receiving an apolarized input optical signal. Still further, the cross-over point for the efficiency of the transverse electric polarization state TE and the efficiency for the transverse magnetic polarization state TM occurs in the C-band wavelength range, and particularly around the midpoint thereof. The high efficiency combined with the location of the efficiency cross-over point result in embodiment F of diffraction grating 1 providing enhanced optical performance in the C-band wavelength range.

Referring to Figure 8, there is shown a side view of a preferred embodiment of a wavelength division multiplexing/demultiplexing (WDM) device 10 in accordance with the present invention. The WDM device 10 comprises a plurality of first optical fiber lines or carriers 12, a corresponding plurality of first coupling components 14, a collimating/focusing lens 16 assembly, a prism 17, reflective diffraction grating 1, a second coupling component 20, and a corresponding second optical fiber line or carrier 22. All of the above-identified components



of the WDM device 10 are disposed along an optical axis X-X of the WDM 10, as will be described in more detail below.

End portions of the plurality of first optical fiber lines or carriers 12 are grouped into a one-dimensional fiber array (i.e., a 1 x 4 array) by the first coupling components 14, while an end portion of the single second optical fiber 22 is secured to the output fiber coupling component 20. Both the first coupling components 14 and the second coupling component 20 are used for purposes of optical fiber securement, ease of optical fiber handling and precision optical fiber placement within WDM device 10. First and second coupling components may be, for example, a silicon V-groove assembly.

Referring to Figure 9A, there is shown a perspective end view of a portion of the WDM device 10 revealing how the plurality of first optical fibers 12 are grouped into the one-dimensional fiber array by the first coupling components 14, and how the single second optical fiber 22 is secured to the second coupling component 20.

As shown in Figure 9B, the first coupling components 14 and the second coupling component 20 are disposed offset from, but

symmetrically about, the optical axis X-X of the multiplexing device 10 so as to avoid signal interference between a polychromatic optical beam 26 appearing on or directed to second optical fiber 22 and a narrowband optical beam 24 appearing on or directed to any of the plurality of first optical fibers 12, or anywhere else. This offset spacing of the first coupling components 14 from the second coupling component 20 is determined based upon the characteristics of diffraction grating 1, the wavelengths of each of the narrowband optical beams 24, and the focusing power of lens assembly 16.

Lens assembly 16 (Figure 8) is adapted to collimate narrowband optical beams 24 incident thereon. Lens assembly 16 has a relatively high level of transmission efficiency. The lens assembly may include a plano-convex homogeneous refractive index collimating/focusing lens assembly. Each lens in the lens assembly 16 may utilize a refraction glass material having a high index of refraction to insure efficient optic beam transmissions.

Lens assembly 16 is illustrated in the drawings as a triplet lens assembly for exemplary purposes only. It is understood that lens assembly 16 may include other lens types, lens configurations

and/or lens compositions or a different number of lenses. In cases where diffraction grating 1 is concave or otherwise non-planar, the use of lens assembly 16 within WDM device 10 may be unnecessary.

5 Prism 17 is disposed between lens assembly 16 and diffraction grating 1. Prism 17 bends optical signals from lens assembly 16 towards diffraction grating 1. In doing so, prism 17 allows diffraction grating 1 to be angularly disposed within the housing of WDM device 10, as shown in Figure 8. Prism 17 may be in direct contact with material 5 of diffraction grating 1, or spaced therefrom. It is understood, however, that WDM device 1 may be utilized without prism 17.

10 The use of diffraction grating 1 within WDM device 10 results in a high efficiency device for performing substantially polarization insensitive multiplexing/demultiplexing operations. For instance, WDM device 10, in accordance with embodiments of the present invention, may achieve a polarization dependent loss of less than approximately 1 dB, and particularly less than 0.5 dB, with an insertion loss of less than 3 dB. Due in part to the angular dispersion provided by diffraction grating 1, WDM device

10 may handle up to 49 channels with channel spacing of approximately 0.8nm over the C-band or L-band wavelength range. Diffraction grating 1 may be used in the Littrow mode in WDM device 10. With such high efficiency performance, the present WDM device 10 may be utilized as a passive device and in a substantially passive network. By eliminating the need for active components, WDM device 10 of the embodiments of the present invention thereby reduces power and conserves energy.

It is understood that although diffraction grating 1 may be associated with and/or included in passive devices and networks, it is understood that diffraction grating 1 may be utilized in devices and networks having active components which may perform one or more of a variety of active functions, including optical amplification.

The WDM device 10 may further include a set of patterned optical component(not shown). By way of one example, each patterned optical component may be a plano-convex converging patterned optical component having a substantially convex surface on one side with a substantially patterned phase mask superimposed, and the spacing or pitch between adjacent patterned

optical components may progressively increase from one end of the one-dimensional fiber array to the other. The progressively increased pitch may be a function of the diffraction equation of diffraction grating 1. The patterned optical components are discussed in greater detail in U.S. Patent application 09/545,826, which is incorporated by reference herein in its entirety.

The operation of WDM device 10 will be described with reference to Figures 10A-10D. As mentioned above, WDM device 10 is capable of performing both multiplexing and demultiplexing functions. In the context of a multiplexing function, reference is made to Figures 10A and 10B.

In performing a multiplexing function, WDM device 10 generally receives a plurality of individual narrowband optical input signals or beams 24 at different wavelengths and combines such signals to generate a polychromatic output signal or beam 26. Each of the plurality of narrowband optical input beams 24 are transmitted along and emitted from a corresponding first optical fiber 12 into the air space between the first coupling components 14 and lens assembly 16. Within this air space, the plurality of narrowband optical input beams 24 are expanded in diameter (best

seen in Figure 9) until they become incident upon the lens assembly 16. The lens assembly 16 collimates each of the plurality of narrowband optical input beams 24 (Figure 10A), and transmits each collimated, narrowband optical input beam 24' to the diffraction grating 1.

Referring to Figure 10B, diffraction grating 1 operates to angularly reflect the plurality of collimated, narrowband optical input beams 24' back towards lens assembly 16, generally shown as reflected beams 24''. In doing so, the diffraction grating 1 removes the angular or spatial separation of the plurality of collimated, narrowband optical input beams 24''. Lens assembly 16 focuses the reflected beams 24'' towards second coupling component 20. The focused reflected beams 24'' become incident upon the single second optical fiber 22 and combine in a multiplexed polychromatic optical output signal 26 at second coupling component 20. The single collimated, polychromatic optical output beam 26 contains each of the unique wavelengths of the plurality of the narrowband reflected beams 24''. The single multiplexed, polychromatic optical output beam 26 is then coupled

into the single second optical fiber 22 for transmission therethrough.

In the context of performing a demultiplexing operation, the operation of WDM device 10 will be described with reference to Figures 10C and 10D. In performing a demultiplexing function, WDM device 10 generally receives a single polychromatic input signal or beam 26 and generates a plurality of individual narrowband optical signals or beams 24 at different wavelengths from the single polychromatic input signal 26.

A single polychromatic optical input beam 26 is transmitted along and emitted from second optical fiber 22 into the air space between the second coupling component 20 and the lens assembly 16. Within this air space, the polychromatic optical input beam 26 is expanded in diameter (best seen in Figure 9) until it becomes incident upon the lens assembly 16. The lens assembly 16 focuses the polychromatic optical input beam 26 towards diffraction grating 1 as polychromatic optical beam 26' (Figure 10C).

As stated above, diffraction grating 1 operates to angularly diffract the polychromatic optical beam 26' into a plurality of narrowband optical beams 24, with each reflected narrowband beam

24 being diffracted at a distinct angle, relative to diffraction  
grating 1, by an amount that is dependent upon the wavelength of  
the reflected narrowband optical beam 24. As shown in Figure 10D,  
the diffraction grating 1 reflects the narrowband optical signals  
24 back towards the lens assembly 16. The lens assembly 16  
collimates the plurality of narrowband optical input beams 24, and  
then transmits each collimated, narrowband optical beam 24' to  
the corresponding first coupling component 14 and corresponding  
first optical fiber 12. Each narrowband optical beam 24' becomes  
incident upon a corresponding first optical fiber 12. At this  
point, the narrowband optical signals 24' are then coupled to the  
first optical fibers 12 for transmission therethrough.

Figure 11 is a block diagram of a fiber optic network 100 in  
accordance with an embodiment of the present invention. The fiber  
optic network 100 provides optical communication between end  
points 105a, 105b, and 105c. Each end point 105a, 105b, and 105c  
is coupled to a WDM 110a, 110b, and 110c, respectively, either  
optically or electrically. In the case of an optical coupling,  
each end point 105a and 105c communicates a multiple number of  
narrowband optical signals via fiber optic lines or carriers 112a-



112n to the associated WDM 110a-110c, respectively. The end point  
105b communicates a multiple number of narrowband optical signals  
via fiber optic lines or carriers 114a-114d to/from WDM 110b,  
which multiplexes the narrowband optical signals 114b, 114d to WDM  
5 110d along fiber optic line or carrier 116.

The WDMs 110a and 110c are coupled via a wavelength add/drop  
device 120 between the fiber optic lines 122a and 122c,  
respectively. The wavelength add/drop device 120 is, in general  
terms, a simple form of a wavelength router with two input/output  
10 (I/O) ports and an additional third port wherein narrowband  
optical signals are added to/dropped from the incoming  
polychromatic optical signal appearing at either I/O port. Within  
the wavelength add/drop device 120, a pair of WDMs 130a-130b are  
utilized to separate a received polychromatic optical signal into  
15 a plurality of narrowband optical signals and communicate one or  
more of the narrowband optical signals to end point 105b, via the  
WDM 110d.

The present invention is not to be limited in scope by the  
specific embodiments described herein. Indeed, various  
20 modifications of the present invention, in addition to those

[illegible][illegible]

**CLAIMS**

What is claimed is:

1           1. A diffraction grating for diffracting optical signals,  
2           comprising:

3           a substrate; and

4           a layer of material having a first surface adjacent the  
5           substrate and a second surface, the layer of material having a  
6           grating profile designed to diffract one or more input optical  
7           signals as one or more output optical signals over a wavelength  
8           range of at least about 30nm, within which the diffraction grating  
9           is substantially polarization insensitive.

1           2. The diffraction grating of claim 1, wherein:

2           the one or more input optical signals incident on the layer  
3           of material includes a polychromatic signal.

1           3. The diffraction grating of claim 1, wherein:

2           the one or more input optical signals incident on the  
3           reflective material includes a plurality of narrowband optical  
4           signals.

1           4. The diffraction grating of claim 1, wherein:

2           the one or more input optical signals comprises a  
3 polychromatic signal incident the second surface of the layer of  
4 material; and

5           the one or more output optical signals comprising at least  
6 two demultiplexed narrowband optical signals.

1           5. The diffraction grating of claim 1, wherein:

2           the one or more input optical signals comprises a plurality  
3 of narrowband optical signals incident the second surface of the  
4 layer of material; and

5           the one or more output optical signals forming a multiplexed  
6 polychromatic signal.

1           6. The diffraction grating of claim 1, wherein:

2           the output optical signals include transverse electric and  
3 transverse magnetic polarization states, each transverse electric  
4 and transverse magnetic polarization state having at least 60% of  
5 the power of a corresponding transverse electric and transverse

6 magnetic polarization state of the one or more input optical  
7 signals, respectively.

1 7. The diffraction grating of claim 1, wherein:  
2 the diffraction grating has an efficiency of at least 60%  
3 over the wavelength range.

1 8. The diffraction grating of claim 1, wherein:  
2 the output optical signals include transverse electric and  
3 transverse magnetic polarization states, each transverse electric  
4 and transverse magnetic polarization state having at least 80% of  
5 the power of a corresponding transverse electric and transverse  
6 magnetic polarization state, respectively, of the one or more  
7 input optical signals.

1 9. The diffraction grating of claim 1, wherein:  
2 the diffraction grating has an efficiency of at least 80%  
3 over the wavelength range.

1           10. The diffraction grating of claim 1, wherein:

2           the wavelength range includes at least one of the C-band and  
3 L-Band wavelength ranges;

4           the output optical signals include transverse electric and  
5 transverse magnetic polarization states; and

6           the loss of the transverse electric polarization state and  
7 the loss of the transverse magnetic polarization state, relative  
8 to the power level of corresponding transverse electric and  
9 transverse magnetic polarization states of the one or more input  
10 optical signals, respectively, are substantially equal at one or  
11 more wavelengths approximately in the wavelength range.

11. The diffraction grating of claim 1, wherein:

the output optical signals include transverse electric and  
transverse magnetic polarization states; and

for each output optical signal, the difference between the  
loss of the transverse electric polarization state and the loss  
of the transverse magnetic polarization state, relative to the  
power level of corresponding transverse electric and transverse  
magnetic polarization states of the one or more input optical  
signals, respectively, is less than approximately 20% loss.

12. The diffraction grating of claim 1, wherein:

the output optical signals include transverse electric and  
transverse magnetic polarization states; and

for each output optical signal, the difference between the  
loss of the transverse electric polarization state and the loss  
of the transverse magnetic polarization state, relative to the  
power level of corresponding transverse electric and transverse  
magnetic polarization states of the one or more input optical  
signals, respectively, is less than approximately 10% loss.

1           13. The diffraction grating of claim 1, wherein:  
2           the wavelength range includes at least one of the C-band and  
3           L-band wavelength ranges.

1           14. The diffraction grating of claim 1, wherein:  
2           the number of output optical signals is at least 8.



1           15. A method of communicating optical signals, comprising:  
2           receiving one or more input optical signals; and  
3           diffracting the one or more input optical signals into one  
4           or more output optical signals over a wavelength range of at least  
5           30nm, polarization states for the one or more output optical  
6           signals having power levels that are substantially the same as the  
7           power levels of corresponding polarization states of the one or  
8           more input optical signals.

1           16. The method of claim 15, wherein:  
2           the output optical signals include transverse electric and  
3           transverse magnetic polarization states, each transverse electric  
4           and transverse magnetic polarization state having at least 60% of  
5           the power of a corresponding transverse electric and transverse  
6           magnetic polarization state, respectively, of the one or more  
7           input optical signals.

1           17. The method of claim 15, wherein:  
2           the efficiency of the diffracting of the one or more input  
3           optical signals is at least 60% over the wavelength range.

1 18. The method of claim 15, wherein:

2 the output optical signals include transverse electric and  
3 transverse magnetic polarization states, each transverse electric  
4 and transverse magnetic polarization state having at least 80% of  
5 the power of a corresponding transverse electric and transverse  
6 magnetic polarization state, respectively, of the one or more  
7 input optical signals over.

1 19. The method of claim 15, wherein:

2 the efficiency of the diffracting of the one or more input  
3 optical signals is at least 80% over the wavelength range.

1           20. The method of claim 16, wherein:

2           the wavelength range includes at least one of the C-band and  
3           L-band wavelength ranges;

4           the output optical signals include transverse electric and  
5           transverse magnetic polarization states; and

6           the loss of the transverse electric polarization state and  
7           the loss of the transverse magnetic polarization state, relative  
8           to corresponding transverse electric and transverse magnetic  
9           polarization states of the one or more input optical signals,  
10          respectively, are substantially equal at one or more wavelengths  
11          approximately within the wavelength range.

1           21. The method of claim 15, wherein:

2           the output optical signals include transverse electric and  
3           transverse magnetic polarization states; and

4           for each output optical signal, the difference between the  
5           loss of the transverse electric polarization state and the loss  
6           of the transverse magnetic polarization state, relative to the  
7           power level of corresponding transverse electric and transverse  
8           magnetic polarization states of the one or more input optical  
9           signals, respectively, is less than approximately 20% loss.

1           22. The method of claim 15, wherein:

2           the output optical signals include transverse electric and  
3           transverse magnetic polarization states; and

4           for each output optical signal, the difference between the  
5           of the transverse electric polarization state and the loss of the  
6           transverse magnetic polarization state of the output optical  
7           signals, relative to the power level of corresponding transverse  
8           electric and transverse magnetic polarization states of the one  
9           or more input optical signals, respectively, is less than  
10          approximately 10%.

1           23. The method of claim 15, wherein:

2           the wavelength range includes at least one of the C-band and  
3           L-band wavelength ranges.

1           24. The method of claim 15, wherein:

2           the one or more output optical signals comprise at least 8  
3           output optical signals.

1           25. A diffraction grating, comprising:

2           a substrate; and

3           means, associated with the substrate, for receiving one or  
4 more input optical signals directed towards the substrate and  
5 diffracting the one or more input optical signals into one or more  
6 output optical signals over a wavelength range of at least 30nm,  
7 the diffraction grating being substantially polarization  
8 insensitive over the wavelength range.

1           26. The diffraction grating of claim 25, wherein:

2           the one or more output optical signals include transverse  
3 electric and transverse magnetic polarization states, each  
4 transverse electric and transverse magnetic polarization state  
5 having at least 60% of the power of a corresponding transverse  
6 electric and transverse magnetic polarization state, respectively,  
7 of the one or more input optical signals.

1           27. The diffraction grating of claim 25, wherein:

2           the diffraction grating has an efficiency of at least 60%  
3 over the wavelength range.

1           28. The diffraction grating of claim 25, wherein:

2           the one or more output optical signals include transverse  
3           electric and transverse magnetic polarization states, each  
4           transverse electric and transverse magnetic polarization state  
5           having at least 80% of the power of a corresponding transverse  
6           electric and transverse magnetic polarization state, respectively,  
7           of the one or more input optical signals.

1           29. The diffraction grating of claim 25, wherein:

2           the diffraction grating has an efficiency of at least 80%  
3           over the wavelength range.

1           30. The diffraction grating of claim 25, wherein:  
2           the wavelength range includes at least one of the C-band and  
3           L-Band wavelength ranges;  
4           the output optical signals include transverse electric and  
5           transverse magnetic polarization states; and  
6           the loss of the transverse electric polarization state and  
7           the loss of the transverse magnetic polarization state, relative  
8           to the power of the transverse electric and transverse magnetic  
9           polarization states, respectively, of the one or more input  
10          optical signals are equal at one or more wavelengths approximately  
11          within the wavelength range.



1           31. The diffraction grating of claim 25, wherein:

2           the one or more output optical signals include transverse  
3           electric and transverse magnetic polarization states; and

4           for each output optical signal, the difference between the  
5           loss of the transverse electric polarization state and the loss  
6           of the transverse magnetic polarization state, relative to the  
7           power of corresponding transverse electric and transverse magnetic  
8           polarization states of the one or more input optical signals,  
9           respectively, is less than approximately 20% loss.

1           32. The diffraction grating of claim 25, wherein:

2           the one or more output optical signals include transverse  
3           electric and transverse magnetic polarization states; and

4           for each output optical signal, the difference between the  
5           loss of the transverse electric polarization state and the loss  
6           of the transverse magnetic polarization state, relative to the  
7           power of the transverse electric and transverse magnetic  
8           polarization states of the one or more input optical signals,  
9           respectively, is less than approximately 10% loss.

1           33. The diffraction grating of claim 25, wherein:  
2           the wavelength range includes at least one of the C-band and  
3           L-Band wavelength ranges.

1           34. The diffraction grating of claim 25, wherein:  
2           the diffraction grating is capable of diffracting at least  
3           8 output optical signals over the wavelength range.

1           35. A diffraction grating, comprising:  
2           a reflective material having a blazed surface with a blaze  
3 angle between about 27 degrees and about 39 degrees; and  
4           an optically transmissive material disposed adjacent the  
5 reflective material and having an index of refraction (n), wherein  
6 the blazed surface of the reflective material has approximately  
7  $(500 \pm 110) * n$  number of grooves per millimeter.

1           36. The diffraction grating of claim 35, wherein:  
2           the number of grooves per millimeter for the reflective  
3 material is between about 710 and about 790;  
4           the index of refraction of the optically transmissive  
5 material is between about 1.44 and about 1.64; and  
6           the blaze angle is between about 27 and about 32 degrees.

1           37. The diffraction grating of claim 35, wherein:  
2           the diffraction order associated with the lowest loss is the  
3 first order.

1           38. The diffraction grating of claim 35, wherein:

2           the number of grooves per millimeter for the reflective  
3 material is between about 850 and about 950;

4           the index of refraction of the optically transmissive  
5 material is between about 1.44 and about 1.64; and

6           the blaze angle is between about 31 and about 34 degrees.

1           39. The diffraction grating of claim 35, further comprising:

2           the number of grooves per millimeter for the reflective  
3 material is between about 950 and about 1050;

4           the index of refraction of the optically transmissive  
5 material is between about 1.44 and about 1.64; and

6           the blaze angle is between about 34 and about 39 degrees.

1           40. A diffraction grating, comprising:  
2           a reflective material having a sinusoidal surface; and  
3           an optically transmissive material disposed adjacent the  
4           reflective material having an index of refraction (n), wherein the  
5           sinusoidal surface of the reflective material has a groove depth  
6           of approximately  $(500 \pm 110) * n$  in nanometers and approximately  
7            $(685 \pm 40) / n$  number of grooves.

1           41. The diffraction grating of claim 40, wherein:  
2           the number of grooves per millimeter for the reflective  
3           material is between about 700 and about 800; and  
4           the index of refraction of the optically transmissive  
5           material is between about 1.44 and about 1.64.

1           42. The diffraction grating of claim 40, wherein:  
2           the groove depth for the reflective material is between  
3           about 420 and about 470; and  
4           the index of refraction of the optically transmissive  
5           material is between about 1.44 and about 1.64.

1           43. The diffraction grating of claim 40, wherein:  
2           the diffraction order associated with the lowest loss is the  
3           first order.

1           44. The diffraction grating of claim 40, wherein:  
2           the reflective material is at least one of the following:  
3           gold material, aluminum material and silver material.

1           45. The diffraction grating of claim 40, further comprising:  
2           a substantially planar substrate on which the reflective  
3           material is formed.

1           46. A diffraction grating, comprising:

2           a reflective material having a blazed surface with a blaze  
3 angle between about 37 degrees and about 40 degrees; and

4           an optically transmissive material disposed adjacent the  
5 reflective material having an index of refraction (n), wherein the  
6 blazed surface of the reflective material has approximately  
7  $(200 \pm 40) * n$  number of grooves per millimeter.

1           47. The diffraction grating of claim 46, wherein:

2           the number of grooves per millimeter for the reflective  
3 material is between about 260 and about 340; and

4           the index of refraction of the optically transmissive  
5 material is between about 1.44 and about 1.64.

1           48. The diffraction grating of claim 46, wherein:

2           the diffraction order associated with the lowest loss is the  
3 fourth order.

1           49. The diffraction grating of claim 46, wherein:

2           the reflective material is at least one of the following:  
3           gold material, aluminum material and silver material.

1           50. The diffraction grating of claim 46, further comprising:  
2           a substantially planar substrate on which the reflective  
3           material is formed.



1           51. A diffraction grating, comprising:  
2           a reflective material having a blazed surface with a blaze  
3           angle between about 41 degrees and about 44 degrees; and  
4           an optically transmissive material disposed adjacent the  
5           reflective material having an index of refraction (n), wherein the  
6           blazed surface of the reflective material has approximately  
7           (450±40)\*n number of grooves per millimeter.

1           52. The diffraction grating of claim 51, wherein:  
2           the number of grooves per millimeter for the reflective  
3           material is between about 560 and about 640; and  
4           the index of refraction of the optically transmissive  
5           material is between about 1.44 and about 1.64.

1           53. The diffraction grating of claim 51, wherein:  
2           the diffraction order associated with the lowest loss is the  
3           second order.

1           54. The diffraction grating of claim 51, wherein:

2           the reflective material is at least one of the following:  
3           gold material, aluminum material and silver material.

1           55. The diffraction grating of claim 51, further comprising:  
2           a substantially planar substrate on which the reflective  
3           material is formed.

55. The diffraction grating of claim 51, further comprising:  
a substantially planar substrate on which the reflective  
material is formed.

1           56. A diffraction grating, comprising:

2           a reflective material having a blazed surface with a blaze  
3 angle between about 68 degrees and about 76 degrees; and

4           an optically transmissive material disposed adjacent the  
5 reflective material having an index of refraction (n), wherein the  
6 blazed surface has approximately  $(200 \pm 20) * n$  number of grooves per  
7 millimeter.

1           57. The diffraction grating of claim 56, wherein:

2           the number of grooves per millimeter for the reflective  
3 material is between about 180 and about 220; and

4           the index of refraction of the optically transmissive  
5 material is approximately 1.0.

1           58. The diffraction grating of claim 56, wherein:

2           the diffraction order associated with the lowest loss is the  
3 fifth order.

1           59. The diffraction grating of claim 56, wherein:  
2           the reflective material is at least one of the following:  
3           gold material, aluminum material and silver material.

1           60. The diffraction grating of claim 56, further comprising:  
2           a substantially planar substrate on which the reflective  
3           material is formed.

1           61. A diffraction grating, comprising:

2           a reflective material having a blazed surface with a blaze  
3 angle between about 50 degrees and about 56 degrees; and

4           an optically transmissive material disposed adjacent the  
5 reflective material having an index of refraction (n), wherein the  
6 blazed surface of the reflective material has approximately  
7  $(250 \pm 30) * n$  number of grooves per millimeter.

1           62. The diffraction grating of claim 61, wherein:

2           the number of grooves per millimeter for the reflective  
3 material is between about 220 and about 280; and

4           the index of refraction of the optically transmissive  
5 material is approximately 1.0.

1           63. The diffraction grating of claim 61, wherein:

2           the diffraction order associated with the lowest loss is the  
3 fourth order.

- 1
- 2
- 3

1           65. A wavelength division device, comprising:

2           a plurality of first coupling components for supporting a  
3 plurality of a signal carrier;

4           a second coupling component disposed adjacent at least one  
5 of the first coupling components for supporting a signal carrier;  
6 and

7           a diffraction grating disposed relative to and in optical  
8 communication with signal carriers coupled to the first and second  
9 coupling components so as to diffract one or more input optical  
10 rays within the wavelength division device as a plurality of  
11 output optical rays for emission from the wavelength division  
12 device over a wavelength range of at least approximately 30nm,  
13 within the wavelength range the wavelength division device is  
14 substantially polarization insensitive.

1           66. The wavelength division device of claim 65, wherein:  
2           the one or more input optical signals comprises at least one  
3 polychromatic signal;  
4           the one or more output optical signals comprises a plurality  
5 of narrowband optical signals; and  
6           the wavelength division device performs a wavelength  
7 division demultiplexing operation.

1           67. The wavelength division device of claim 65, wherein:  
2           the one or more input optical signals comprises a plurality  
3 of narrowband optical signals;  
4           the one or more output optical signals emitted from the  
5 wavelength division device comprises a polychromatic signal; and  
6           the wavelength division device performs a wavelength  
7 division multiplexing operation.

1           68. The wavelength division device of claim 65, wherein:  
2           the wavelength division device has a polarization dependent  
3 loss of less than approximately 1 dB over the wavelength range.



1           69. The wavelength division device of claim 65, wherein:  
2           the wavelength division device has a polarization dependent  
3           loss of less than approximately 0.5 dB over the wavelength range.

1           70. The wavelength division device of claim 65, wherein:  
2           the number of output optical rays comprise at least 8.

1           71. The wavelength division device of claim 65, wherein:  
2           the diffracted output optical rays include transverse  
3           electric and transverse magnetic polarization states, each  
4           transverse electric and transverse magnetic polarization state  
5           having at least 60% of the power of a corresponding transverse  
6           electric and transverse magnetic polarization state, respectively,  
7           of the one or more input optical signals.

1           72. The wavelength division device of claim 65, wherein:  
2           the diffraction grating has an efficiency of at least 60%  
3           over the wavelength range.

1           73. The wavelength division device of claim 65, wherein:  
2           the diffracted output optical rays include transverse  
3           electric and transverse magnetic polarization states, each  
4           transverse electric and transverse magnetic polarization state  
5           having at least 80% of the power of a corresponding transverse  
6           electric and transverse magnetic polarization state, respectively,  
7           of the one or more input optical rays.

1           74. The wavelength division device of claim 65, wherein:  
2           the diffraction grating has an efficiency of at least 80%  
3           over the wavelength range.

1           75. The wavelength division device of claim 65, wherein:  
2           the wavelength range includes at least one of the C-band  
3           wavelength range and the L-band wavelength range;  
4           the diffracted output optical rays include transverse  
5           electric and transverse magnetic polarization states; and  
6           the loss of the transverse electric polarization state and  
7           the loss of the transverse magnetic polarization state, relative  
8           to power levels of corresponding transverse electric and  
9           transverse magnetic polarization states, respectively, of the one  
10          or more input optical signals are substantially equal at one or  
11          more wavelengths approximately within the wavelength range.

1           76. The wavelength division device of claim 65, wherein:  
2           the diffracted output optical rays include transverse  
3           electric and transverse magnetic polarization states; and  
4           for each output optical signal, the difference between the  
5           loss of the transverse electric polarization state and the loss  
6           of the transverse magnetic polarization state, relative to power  
7           levels of corresponding transverse electric and transverse  
8           magnetic polarization states, respectively, of the one or more  
9           input optical signals is less than approximately 20% loss.

1           77. The wavelength division device of claim 65, wherein:  
2           the diffracted output optical rays include transverse  
3           electric and transverse magnetic polarization states; and  
4           for each output optical signal, the difference between the  
5           loss of the transverse electric polarization state and the loss  
6           of the transverse magnetic polarization state, relative to power  
7           levels of corresponding transverse electric and transverse  
8           magnetic polarization states, respectively, of the one or more  
9           input optical signals is less than approximately 10% loss.

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78. The wavelength division device of claim 65, wherein:  
the wavelength range includes at least one of the C-band and  
L-band wavelength ranges.

1           79. A method of performing an operation on an optical  
2 signal, comprising:

3           receiving one or more input optical signals;

4           diffracting the one or more input optical signals into a  
5 plurality of output optical signals, each output optical signal  
6 having a distinct wavelength and being diffracted at a distinct  
7 angle within a wavelength range of at least 30nm and having  
8 polarization states whose power levels are substantially the same  
9 as power levels of corresponding polarization states of the one  
10 or more input optical signals; and

11          coupling each output optical signal onto a distinct carrier.

1           80. The method of claim 79, wherein:

2           the one or more output optical signals include transverse  
3 electric and transverse magnetic polarization states, each  
4 transverse electric and transverse magnetic polarization state  
5 having at least 60% of the power of a corresponding transverse  
6 electric and transverse magnetic polarization state, respectively,  
7 of the one or more input optical signals.

1           81. The method of claim 79, wherein:

2           the efficiency of the diffracting of the one or more input  
3           optical signals is at least 60% over the wavelength range.

1           82. The method of claim 79, wherein:

2           the one or more output optical signals include transverse  
3           electric and transverse magnetic polarization states, each  
4           transverse electric and transverse magnetic polarization state  
5           having at least 80% of the power of a corresponding transverse  
6           electric and transverse magnetic polarization state, respectively,  
7           of the one or more input optical signals.

1           83. The method of claim 79, wherein:

2           the efficiency of the diffracting of the one or more input  
3           optical signals is at least 80% over the wavelength range.

1           84. The method of claim 79, wherein:

2           the wavelength range includes at least one of the C-band and  
3 L-band wavelength ranges;

4           the one or more output optical signals include transverse  
5 electric and transverse magnetic polarization states; and

6           the loss of the transverse electric polarization state and  
7 the loss of the transverse magnetic polarization state, relative  
8 to power levels of corresponding transverse electric and  
9 transverse magnetic polarization states of the one or more input  
10 optical signals, respectively, are substantially equal at one or  
11 more wavelengths approximately within the wavelength range.



1           85. The method of claim 79, wherein:

2           the one or more output optical signals include transverse  
3           electric and transverse magnetic polarization states; and

4           for each output optical signal, the difference between the  
5           loss of the transverse electric polarization state and the loss  
6           of the transverse magnetic polarization state, relative to power  
7           levels of corresponding transverse electric and transverse  
8           magnetic polarization states of the one or more input optical  
9           signals, respectively, is less than approximately 20%.

1           86. The method of claim 79, wherein:

2           the one or more output optical signals include transverse  
3           electric and transverse magnetic polarization states; and

4           for each output optical signal, the difference between the  
5           loss of the transverse electric polarization state and the loss  
6           of the transverse magnetic polarization state, relative to power  
7           levels of corresponding transverse electric and transverse  
8           magnetic polarization states of the one or more input optical  
9           signals, respectively, is less than approximately 10%.

1           87. The method of claim 79, wherein:  
2           the wavelength range includes at least one of the C-band and  
3           L-band wavelength ranges.

1           88. The method of claim 79, further comprising:  
2           collimating the diffracted output optical signals.

1           89. The method of claim 79, wherein the diffracting  
2           comprises:  
3           diffracting the one or more input optical signals into at  
4           least 8 output optical signals.

1           90. A wavelength division device, comprising:  
2           a means for receiving one or more input optical signals;  
3           a means for diffracting the one or more input optical  
4 signals into a plurality of output optical signals, each output  
5 optical signal having a distinct wavelength and being diffracted  
6 at a distinct angle within a wavelength range of at least 30nm and  
7 having polarization states whose power levels are substantially  
8 the same as power levels of polarization states of a corresponding  
9 one of the one or more input optical signals; and  
10          a means for coupling each output optical signal onto a  
11 distinct carrier.

1           91. The wavelength division device of claim 90, wherein:  
2           the one or more output optical signals include transverse  
3 electric and transverse magnetic polarization states, each  
4 transverse electric and transverse magnetic polarization state  
5 having at least 60% of the power of a corresponding transverse  
6 electric and transverse magnetic polarization state, respectively,  
7 of the one or more input optical signals.

1           92. The wavelength division device of claim 90, wherein:  
2           the efficiency of the diffracting of the one or more input  
3           optical signals is at least 60% over the wavelength range.

1           93. The wavelength division device of claim 90, wherein:  
2           the one or more output optical signals include transverse  
3           electric and transverse magnetic polarization states, each  
4           transverse electric and transverse magnetic polarization state  
5           having at least 80% of the power of a corresponding transverse  
6           electric and transverse magnetic polarization state, respectively,  
7           of the one or more input optical signals.

1           94. The wavelength division device of claim 90, wherein:  
2           the efficiency of the diffracting of the one or more input  
3           optical signals is at least 80% over the wavelength range.

1           95. The wavelength division device of claim 90, wherein:  
2           the wavelength range includes at least one of the C-band and  
3           L-band wavelength ranges;  
4           the one or more output optical signals include transverse  
5           electric and transverse magnetic polarization states; and  
6           the loss of the transverse electric polarization state and  
7           the loss of the transverse magnetic polarization state, relative  
8           to power levels of corresponding transverse electric and  
9           transverse magnetic polarization states, respectively, of the one  
10          or more input optical signals are substantially equal at one or  
11          more wavelengths approximately within the wavelength range.

1           96. The wavelength division device of claim 90, wherein:  
2           the one or more output optical signals include transverse  
3           electric and transverse magnetic polarization states; and  
4           for each output optical signal, the difference between the  
5           loss of the transverse electric polarization state and the loss  
6           of the transverse magnetic polarization state, relative to power  
7           levels of corresponding transverse electric and transverse  
8           magnetic polarization states of the one or more input optical  
9           signals, respectively, is less than approximately 20%.

1           97. The wavelength division device of claim 90, wherein:  
2           the one or more output optical signals include transverse  
3           electric and transverse magnetic polarization states; and  
4           for each output optical signal, the difference between the  
5           loss of the transverse electric polarization state and the loss  
6           of the transverse magnetic polarization state, relative to power  
7           levels of corresponding transverse electric and transverse  
8           magnetic polarization states of the one or more input optical  
9           signals, respectively, is less than approximately 10%.

1           98. The wavelength division device of claim 90, wherein:  
2           the wavelength range includes at least one of the C-band and  
3           L-band wavelength ranges.

1           99. The wavelength division device of claim 90, wherein:  
2           the number of output optical signals is at least 8.

1           100. The wavelength division device of claim 90, further  
2           comprising:

3           a means for collimating the diffracted output optical  
4           signals.

1           101. A wavelength division device, comprising:

2           a plurality of first coupling components, each first  
3           component being capable of receiving a distinct carrier for  
4           carrying a signal;

5           a second coupling component disposed adjacent the first  
6           coupling components and capable of receiving a distinct carrier  
7           for carrying one or more signals; and

8           a diffraction grating optically coupled to each carrier  
9           received by the first and second coupling components, comprising:

10           a blazed reflective material having a number of grooves  
11           per millimeter and a blazed angle between about 27 degrees and  
12           about 39 degrees; and

13           an optically transmissive material disposed adjacent  
14           the reflective material having an index of refraction  $(n)$ , wherein  
15           the number of grooves is approximately equal to  $(500 \pm 110) * n$ .



1           102. The wavelength division device of claim 101, wherein:  
2           the index of refraction of the optically transmissive  
3 material is between about 1.44 and about 1.64;  
4           the number of grooves per millimeter on the diffraction  
5 grating is between about 710 and about 790; and  
6           the blaze angle is between about 27 degrees and about 32  
7 degrees.

1           103. The wavelength division device of claim 101, wherein:,  
2 wherein:  
3           the diffraction order associated with the lowest loss is the  
4 first order.

1           104. The wavelength division device of claim 101, wherein:  
2           the index of refraction of the optically transmissive  
3 material is between about 1.44 and about 1.64;  
4           the number of grooves per millimeter on the diffraction  
5 grating is between about 850 and about 950; and  
6           the blaze angle is between about 32 degrees and about 34  
7 degrees.

1           105. The wavelength division device of claim 101, wherein:  
2           the index of refraction of the optically transmissive  
3           material is between about 1.44 and about 1.64;  
4           the number of grooves per millimeter on the diffraction  
5           grating is between about 950 and about 1050; and  
6           the blaze angle is between about 34 degrees and about 39  
7           degrees.

1           106. A wavelength division device, comprising:

2           a plurality of first coupling components, each first  
3 component being capable of receiving a distinct carrier for  
4 carrying a signal;

5           a second coupling component disposed adjacent the first  
6 coupling components and capable of receiving a distinct carrier  
7 for carrying one or more signals; and

8           a diffraction grating optically coupled to each carrier  
9 received by the first and second coupling components, comprising:

10           a reflective material with a sinusoidal surface having  
11 a number of grooves per millimeter and a groove depth in nm; and

12           an optically transmissive material disposed adjacent  
13 the reflective material having an index of refraction (n), wherein  
14 the number of grooves is approximately equal to  $(500 \pm 110) * n$  and  
15 the groove depth is approximately  $(685 \pm 40) / n$ .  
16

17           107. The wavelength division device of claim 106, wherein:  
18           the index of refraction of the optically transmissive  
19 material is between about 1.44 and 1.64; and  
20           the reflective material of the diffraction grating has a  
            groove depth between about 420nm and about 470nm.

1           108. The wavelength division device of claim 106, wherein:  
2           the diffraction order associated with the lowest loss is the  
3 first order.

1           109. The wavelength division device of claim 106, wherein:  
2           the reflective material of the diffraction grating is at  
3 least one of the following: gold material, aluminum material and  
4 silver material.

1           110. The wavelength division device of claim 106, wherein:  
2           the diffraction grating includes a substantially planar  
3 substrate on which the reflective material is disposed.

1           111. The wavelength division device of claim 106, wherein:  
2           the index of refraction is between about 1.44 and 1.64; and  
3           the number of grooves per millimeter is between about 700  
4           and about 800.

111. The wavelength division device of claim 106, wherein:  
the index of refraction is between about 1.44 and 1.64; and  
the number of grooves per millimeter is between about 700  
and about 800.

112. A wavelength division device, comprising:

a plurality of first coupling components, each first component being capable of receiving a distinct carrier for carrying a signal;

a second coupling component disposed adjacent the first coupling components and capable of receiving a distinct carrier for carrying one or more signals; and

a diffraction grating optically coupled to each carrier received by the first and second coupling components, comprising:

a blazed reflective material having a number of grooves per millimeter and a blaze angle between about thirty-seven and about forty degrees; and

an optically transmissive material disposed adjacent the reflective material having an index of refraction (n), wherein the number of grooves is approximately equal to  $(200 \pm 40) * n$ .

1           113. The wavelength division device of claim 112, wherein:  
2           the diffraction order associated with the lowest loss is the  
3           fourth order.

1           114. The wavelength division device of claim 112, wherein:  
2           the reflective material comprises at least one of the  
3           following materials: gold material, aluminum material and silver  
4           material.

1           115. The wavelength division device of claim 112, wherein:  
2           the index of refraction is between about 1.44 and about  
3           1.64; and  
4           the number of grooves per millimeter of the diffraction  
5           grating is between about 260 and about 340.

1           116. The wavelength division device of claim 112, wherein:  
2           the diffraction grating includes a substantially planar  
3           substrate.

117. A wavelength division device, comprising:

a plurality of first coupling components, each first component being capable of receiving a distinct carrier for carrying a signal;

a second coupling component disposed adjacent the first coupling components and capable of receiving a distinct carrier for carrying one or more signals; and

a diffraction grating optically coupled to each carrier received by the first and second coupling components, comprising:

a blazed reflective material having a number of grooves per millimeter and a blaze angle between about forty-one and about forty-four degrees; and

an optically transmissive material disposed adjacent the reflective material having an index of refraction (n), wherein the number of grooves is approximately equal to  $(450 \pm 40) * n$ .



1           118. The wavelength division device of claim 117, wherein:  
2           the diffraction order associated with the lowest loss is the  
3           second order.

1           119. The wavelength division device of claim 117, wherein:  
2           the reflective material of the diffraction grating comprises  
3           at least one of the following materials: gold material, silver  
4           material and aluminum material.

1           120. The wavelength division device of claim 117, wherein:  
2           the index of refraction is between about 1.44 and about  
3           1.64; and  
4           the number of grooves per millimeter on the diffraction  
5           grating is between about 560 and about 640.

1           121. The wavelength division device of claim 117, wherein:  
2           the diffraction grating includes a substantially planar  
3           substrate.

122. A wavelength division device, comprising:

a plurality of first coupling components, each first component being capable of receiving a distinct carrier for carrying a signal;

a second coupling component disposed adjacent the first coupling components and capable of receiving a distinct carrier for carrying one or more signals; and

a diffraction grating optically coupled to each carrier received by the first and second coupling components, comprising:

a blazed reflective material having a number of grooves per millimeter and a blaze angle between about sixty-eight and about seventy-six degrees; and

an optically transmissive material disposed adjacent the reflective material having an index of refraction (n), wherein the number of grooves is approximately equal to  $(200 \pm 20) * n$ .

123. The wavelength division device of claim 122, wherein:

the diffraction order associated with the lowest loss is the fifth order.

1           124. The wavelength division device of claim 122, wherein:  
2           the reflective material of the diffraction grating comprises  
3           at least one of the following materials: gold material, aluminum  
4           material and silver material.

1           125. The wavelength division device of claim 122, wherein:  
2           the index of refraction is approximately one; and  
3           the number of grooves per millimeter appearing on the  
4           diffraction grating is between about 180 and about 220.

1           126. The wavelength division device of claim 122, wherein:  
2           the diffraction grating includes a substantially planar  
3           substrate.

1           127. A wavelength division device, comprising:

2           a plurality of first coupling components, each first  
3           component being capable of receiving a distinct carrier for  
4           carrying a signal;

5           a second coupling component disposed adjacent the first  
6           coupling components and capable of receiving a distinct carrier  
7           for carrying one or more signals; and

8           a diffraction grating optically coupled to each carrier  
9           received by the first and second coupling components, comprising:

10           a blazed reflective material having a blazed surface  
11           with a blaze angle between about fifty and about fifty-six  
12           degrees; and

13           an optically transmissive material disposed  
14           substantially adjacent the reflective material having an  
15           index of refraction, the reflective material having a number  
16           of grooves per millimeter being within a range approximately  
17           defined by the equation  $(250 \pm 30) * n$ , wherein  $n$  is the index  
18           of refraction of the optically transmissive material.

1           128. The wavelength division device of claim 127, wherein:  
2           the diffraction order associated with the lowest loss is the  
3           fourth order.

1           129. The wavelength division device of claim 127, wherein:  
2           the reflective material of the diffraction grating comprises  
3           at least one of the following materials: gold material, aluminum  
4           material and silver material.

1           130. The wavelength division device of claim 127, wherein:  
2           the diffraction grating includes a substantially planar  
3           substrate.

1           131. The wavelength division device of claim 127, wherein:  
2           the index of refraction of the optically transmissive  
3           material is approximately one; and  
4           the number of grooves per millimeter appearing on the  
5           diffraction grating is between about 220 and about 280.

1           132. A communications system utilizing optical  
2 communication, comprising:

3           a plurality of carriers; and

4           a wavelength division device, comprising:

5                 a plurality of first coupling components, each first  
6 component coupling a distinct carrier for carrying at least  
7 one signal within the wavelength division device;

8                 a second coupling component disposed adjacent the first  
9 coupling components and coupling a distinct carrier for  
10 carrying one or more signals within the wavelength division  
11 device; and

12                 a diffraction grating disposed relative to and in  
13 optical communication with the carriers coupled to the first  
14 and second coupling components so as to diffract one or more  
15 input optical rays as a plurality of output optical rays  
16 over a wavelength range of at least approximately 30nm,  
17 within the wavelength range the wavelength division device  
18 is substantially polarization insensitive.

1           133. The communications system of claim 132, wherein:  
2           the wavelength division device has a polarization dependent  
3           loss of less than approximately 1 dB over the wavelength range.

1           134. The communications system of claim 132, wherein:  
2           the wavelength division device has a polarization dependent  
3           loss of less than approximately 0.5 dB over the wavelength range.

1           135. The communications system of claim 132, wherein the WDM  
2           device further comprises:

3           a collimating lens assembly disposed between the first and  
4           second coupling components and the diffraction grating so as to  
5           collimate output optical rays emitted from the carriers coupled  
6           to the first components.

1           136. The communications system of claim 132, wherein:  
2           the output optical rays include transverse electric and  
3           transverse magnetic polarization states, each transverse electric  
4           and transverse magnetic polarization state having at least 60% of  
5           the power of a corresponding transverse electric and transverse  
6           magnetic polarization state, respectively, of the one or more  
7           input optical rays.

1           137. The communications system of claim 132, wherein:  
2           the diffraction grating has an efficiency of at least 60%  
3           over the wavelength range.

1           138. The communications system of claim 132, wherein:  
2           the output optical rays include transverse electric and  
3           transverse magnetic polarization states, each transverse electric  
4           and transverse magnetic polarization state having at least 80% of  
5           the power of a corresponding transverse electric and transverse  
6           magnetic polarization state, respectively, of the one or more  
7           input optical rays.



1           139. The communications system of claim 132, wherein:  
2           the diffraction grating has an efficiency of at least 80%  
3           over the wavelength range.

1           140. The communications system of claim 132, wherein:  
2           the wavelength range includes at least one of the C-band and  
3           L-band wavelength ranges.

1           141. The communications system of claim 132, wherein:  
2           the output optical rays include transverse electric and  
3           transverse magnetic polarization states; and

4           for each output optical signal, the difference between the  
5           loss of the transverse electric polarization state and the loss  
6           of the transverse magnetic polarization state, relative to  
7           corresponding transverse electric and transverse magnetic  
8           polarization states of the one or more optic rays, respectively,  
9           is less than approximately 20% loss.

1 142. The communications system of claim 132, wherein:  
2 the output optical rays include transverse electric and  
3 transverse magnetic polarization states; and  
4 for each output optical signal, the difference between the  
5 loss of the transverse electric polarization state and the loss  
6 of the transverse magnetic polarization state, relative to  
7 corresponding transverse electric and transverse magnetic  
8 polarization states of the one or more optic rays, respectively,  
9 is less than approximately 10% loss.

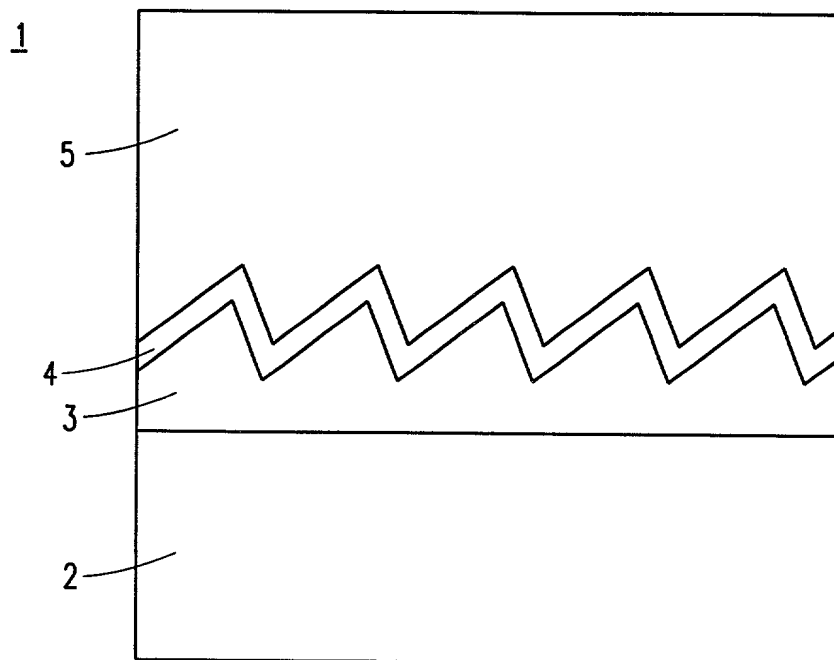
1 143. The communications system of claim 132, wherein:  
2 the number of output optical rays is at least 8.

1 144. The communications system of claim 132, wherein:  
2 the one or more input optical signals comprises at least one  
3 polychromatic signal;  
4 the one or more output optical signals comprises a plurality  
5 of narrowband optical signals; and  
6 the wavelength division device performs an optical  
7 demultiplexing operation.

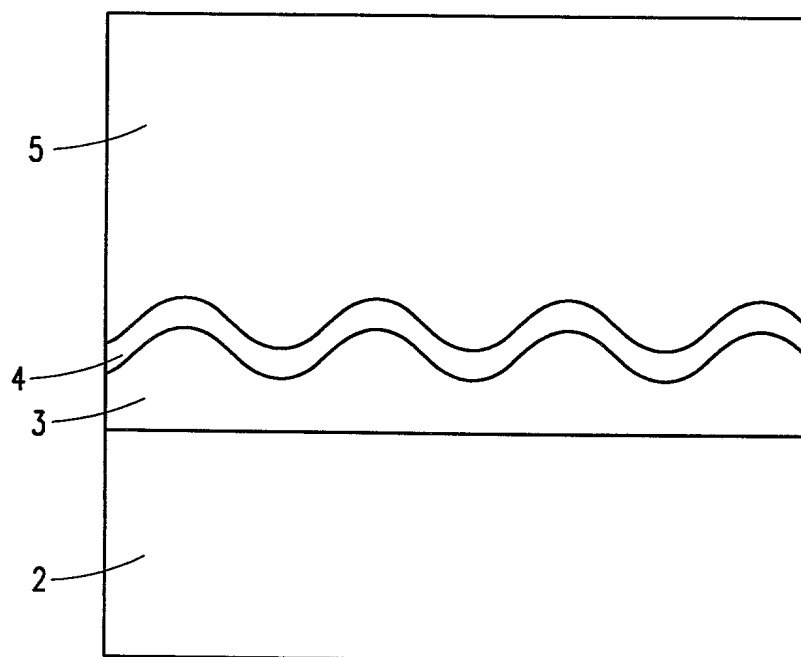
1           145. The communications system of claim 132, wherein:  
2           the one or more input optical signals comprises a plurality  
3 of narrowband optical signals;  
4           the one or more output optical signals emitted from the  
5 wavelength division device comprises a polychromatic signal; and  
6           the wavelength division device performs an optical  
7 multiplexing operation.

Country	Year	Population (millions)	GDP (billion USD)	Urban population (millions)	Urban population (%)	Population density (per sq km)	Life expectancy (years)	Infant mortality (per 1,000 live births)	Health expenditure (billion USD)	Health expenditure (%)
Algeria	2000	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2001	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2002	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2003	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2004	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2005	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2006	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2007	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2008	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2009	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2010	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2011	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2012	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2013	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2014	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2015	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2016	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2017	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2018	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2019	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2020	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2021	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2022	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2023	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2024	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2025	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2026	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2027	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2028	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2029	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2030	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2031	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2032	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2033	24.0	10.0	10.0	41.7	16.0	72.0	10.0	0.5	0.5
Algeria	2034	24.0	10.0	10.0	41.7	16.0	72.0			

Variable	Mean	SD	Min	Max
Age	38.5	12.5	18	65
Gender	Male	Female		
Marital status	Married	Single		
Education	High school	College		
Occupation	Manager	Worker		
Income	Low	High		
Health status	Good	Poor		
Stress level	Low	High		
Life satisfaction	High	Low		
Resilience	High	Low		
Optimism	High	Low		
Self-efficacy	High	Low		
Perceived social support	High	Low		
Perceived stress	Low	High		
Depression	Low	High		
Anxiety	Low	High		
Quality of life	High	Low		
Health-related quality of life	High	Low		
Functional status	High	Low		
Physical functioning	High	Low		
Role functioning	High	Low		
Bodily pain	Low	High		
General health	High	Low		
Energy/fatigue	High	Low		
Sleeping	High	Low		
Appetite	High	Low		
Weight change	Stable	Change		
Medication use	Yes	No		
Comorbidities	Yes	No		
Healthcare utilization	High	Low		
Health insurance	Yes	No		
Health literacy	High	Low		
Health beliefs	High	Low		
Health behaviors	High	Low		
Health status	High	Low		
Health-related quality of life	High	Low		
Functional status	High	Low		
Physical functioning	High	Low		
Role functioning	High	Low		
Bodily pain	Low	High		
General health	High	Low		
Energy/fatigue	High	Low		
Sleeping	High	Low		
Appetite	High	Low		
Weight change	Stable	Change		
Medication use	Yes	No		
Comorbidities	Yes	No		
Healthcare utilization	High	Low		
Health insurance	Yes	No		
Health literacy	High	Low		
Health beliefs	High	Low		
Health behaviors	High	Low		
Health status	High	Low		
Health-related quality of life	High	Low		
Functional status	High	Low		
Physical functioning	High	Low		
Role functioning	High	Low		
Bodily pain	Low	High		
General health	High	Low		
Energy/fatigue	High	Low		
Sleeping	High	Low		
Appetite	High	Low		
Weight change	Stable	Change		
Medication use	Yes	No		
Comorbidities	Yes	No		
Healthcare utilization	High	Low		
Health insurance	Yes	No		
Health literacy	High	Low		
Health beliefs	High	Low		
Health behaviors	High	Low		
Health status	High	Low		
Health-related quality of life	High	Low		
Functional status	High	Low		
Physical functioning	High	Low		
Role functioning	High	Low		
Bodily pain	Low	High		
General health	High	Low		
Energy/fatigue	High	Low		
Sleeping	High	Low		
Appetite	High	Low		
Weight change	Stable	Change		
Medication use	Yes	No		
Comorbidities	Yes	No		
Healthcare utilization	High	Low		
Health insurance	Yes	No		
Health literacy	High	Low		
Health beliefs	High	Low		
Health behaviors	High	Low		
Health status	High	Low		
Health-related quality of life	High	Low		
Functional status	High	Low		
Physical functioning	High	Low		
Role functioning	High	Low		
Bodily pain	Low	High		
General health	High	Low		
Energy/fatigue	High	Low		
Sleeping	High	Low		
Appetite	High	Low		
Weight change	Stable	Change		
Medication use	Yes	No		
Comorbidities	Yes	No		
Healthcare utilization	High	Low		



*FIG. 1A*



*FIG. 1B*

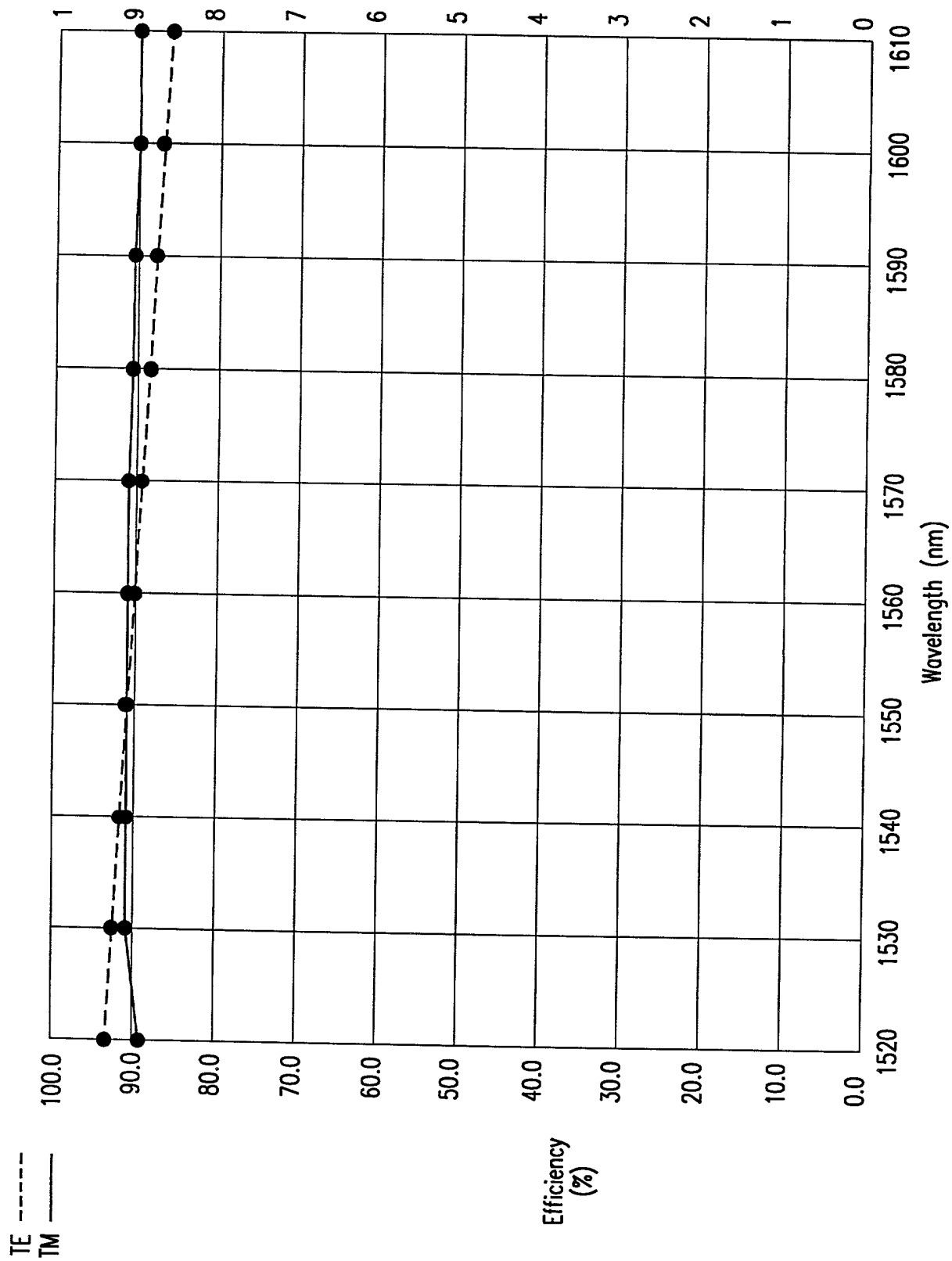


FIG. 2

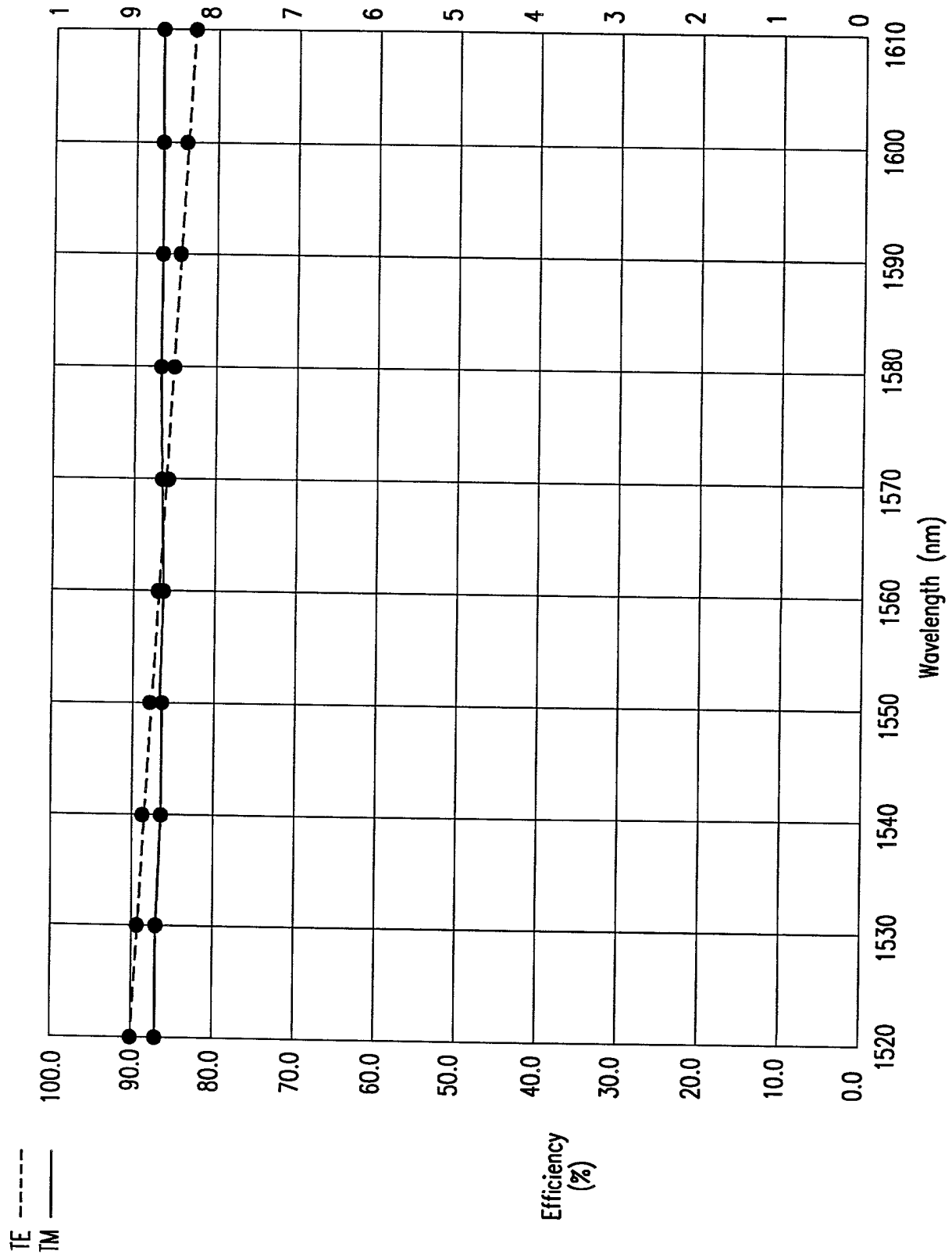


FIG. 3

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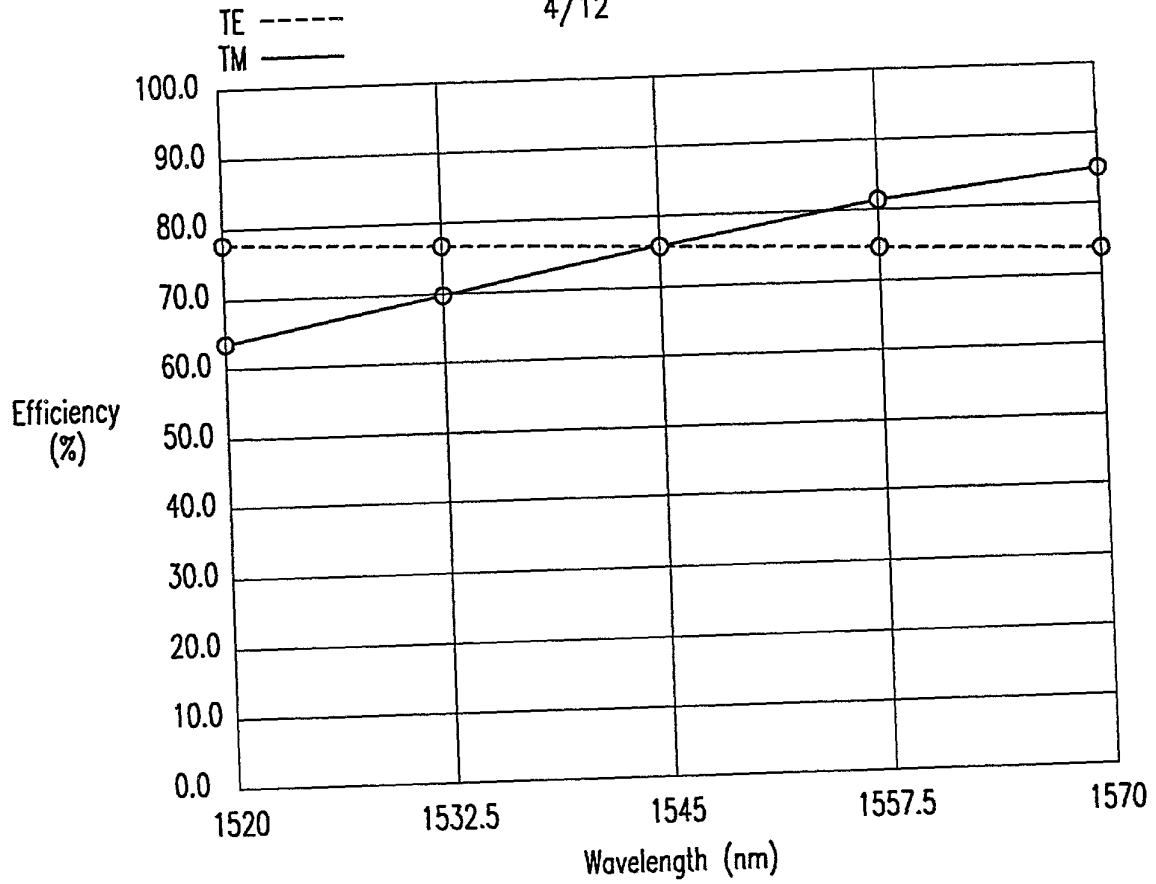


FIG. 4

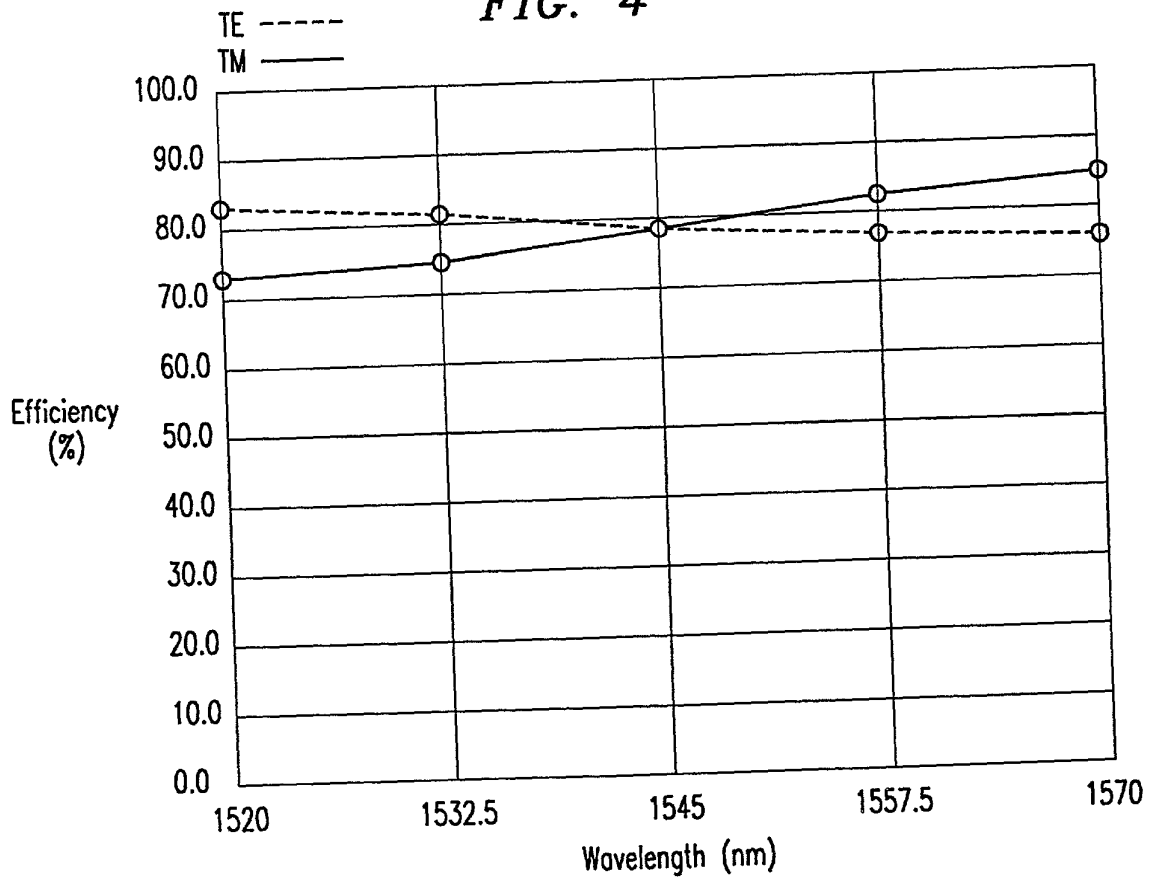


FIG. 5



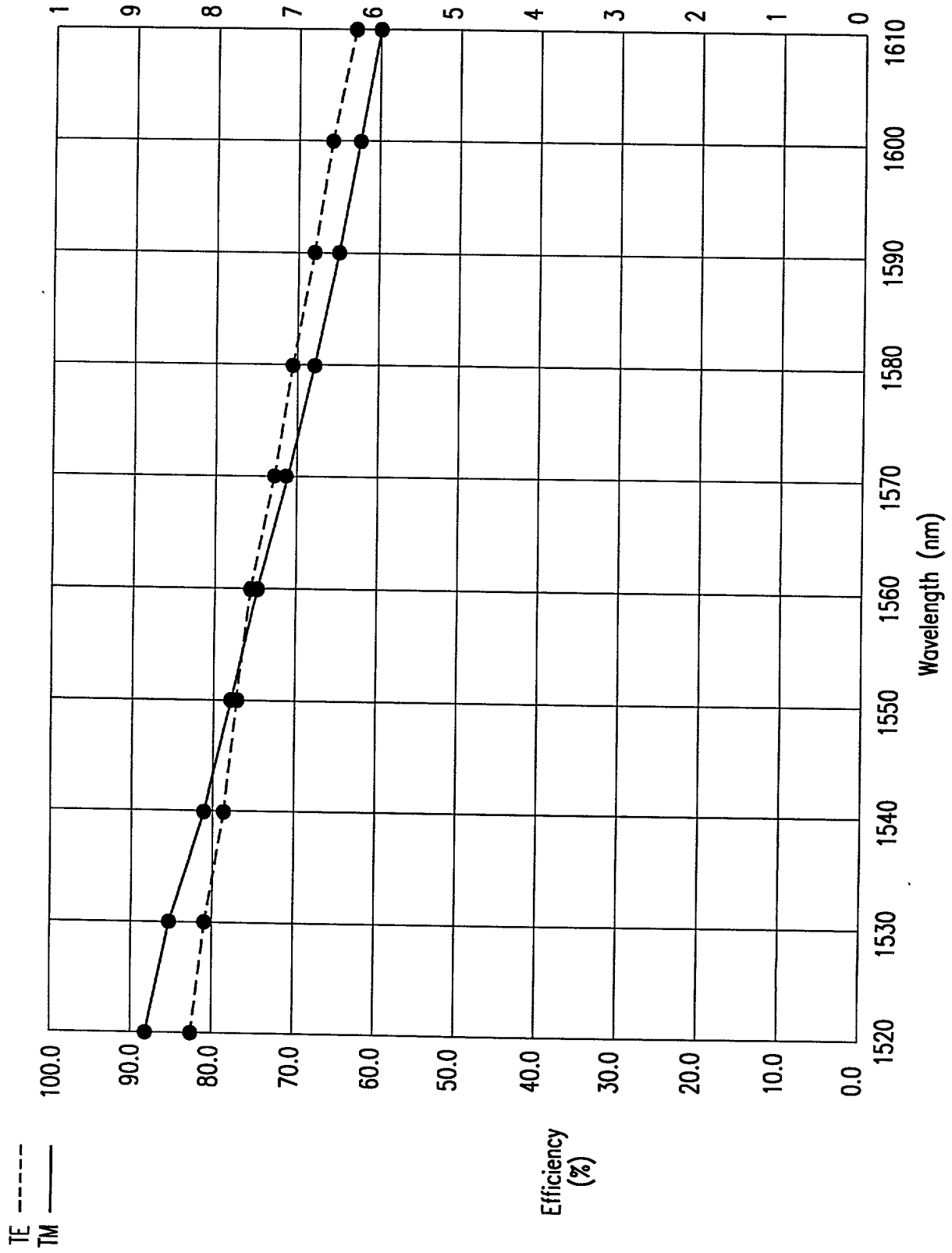
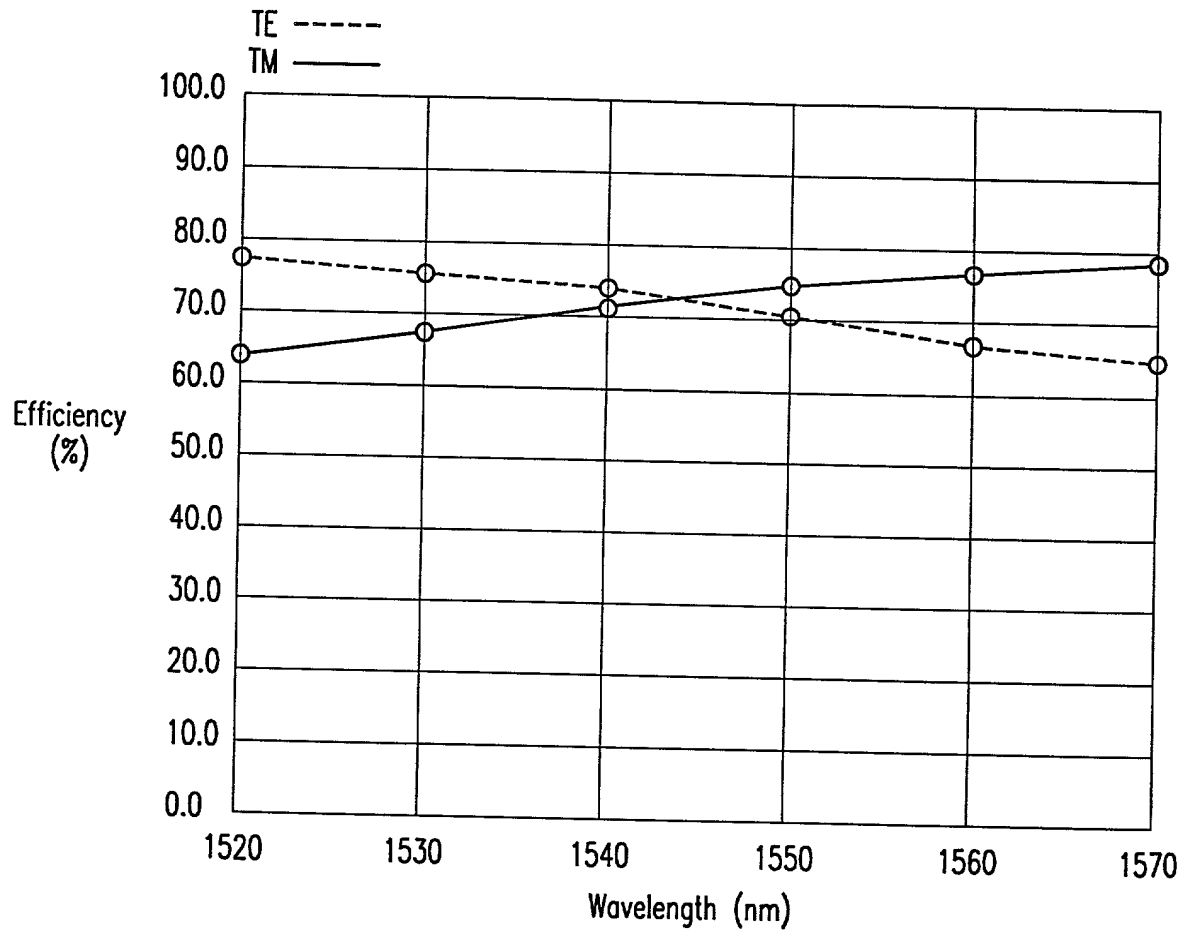


FIG. 6

*FIG. 7*

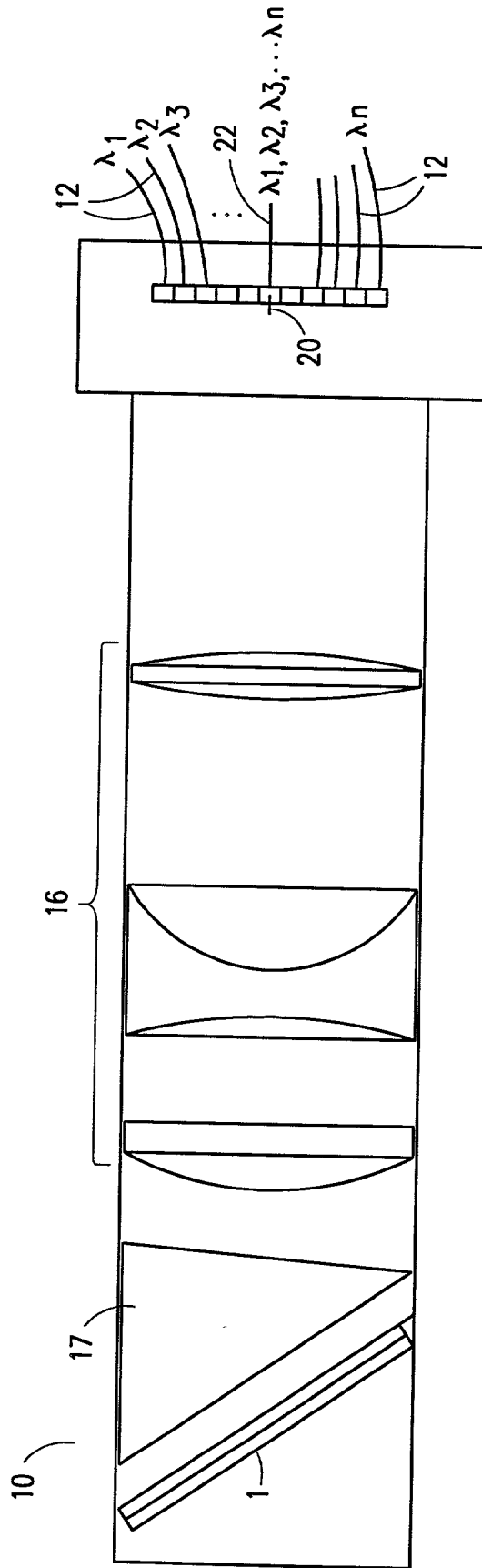


FIG. 8

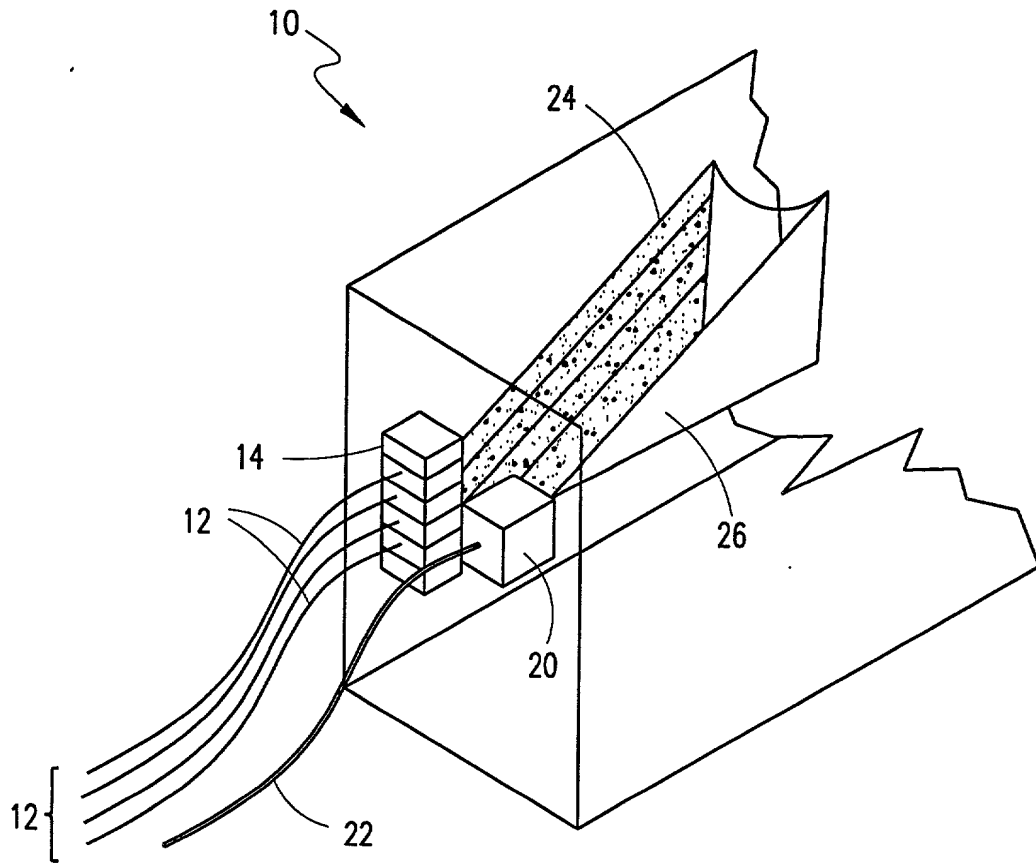


FIG. 9A

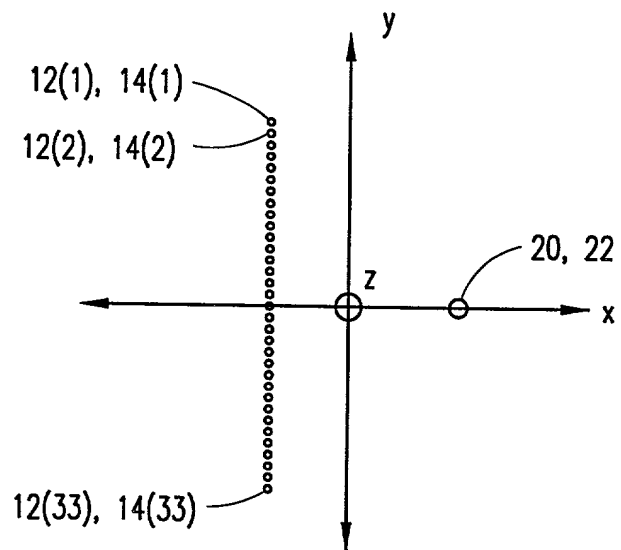
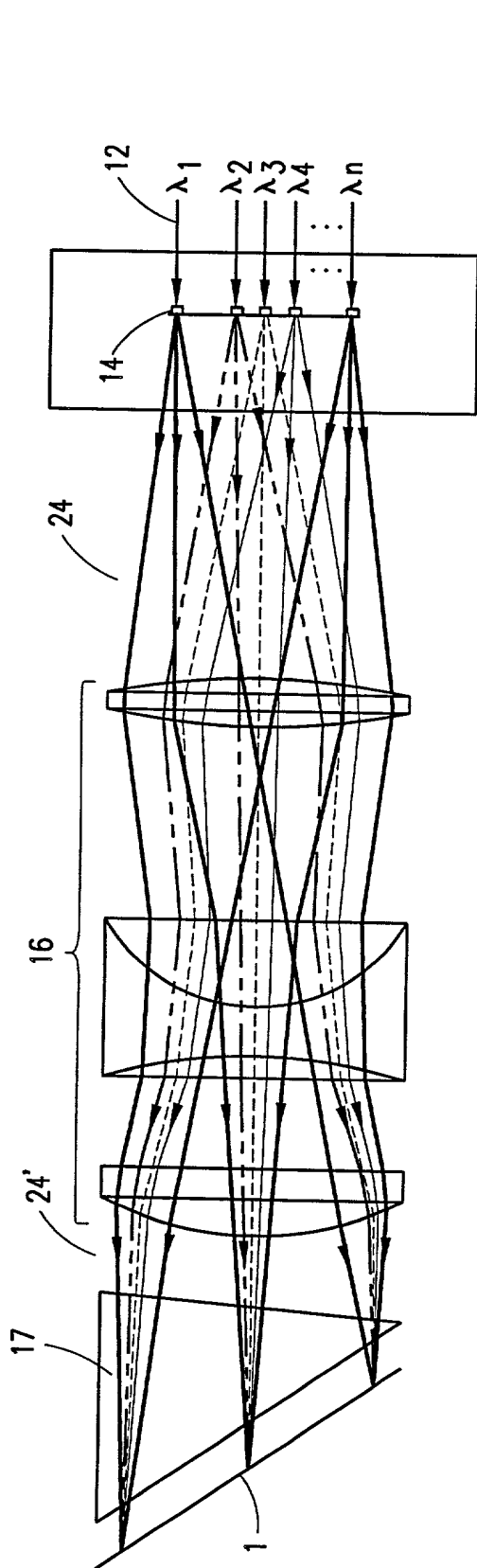
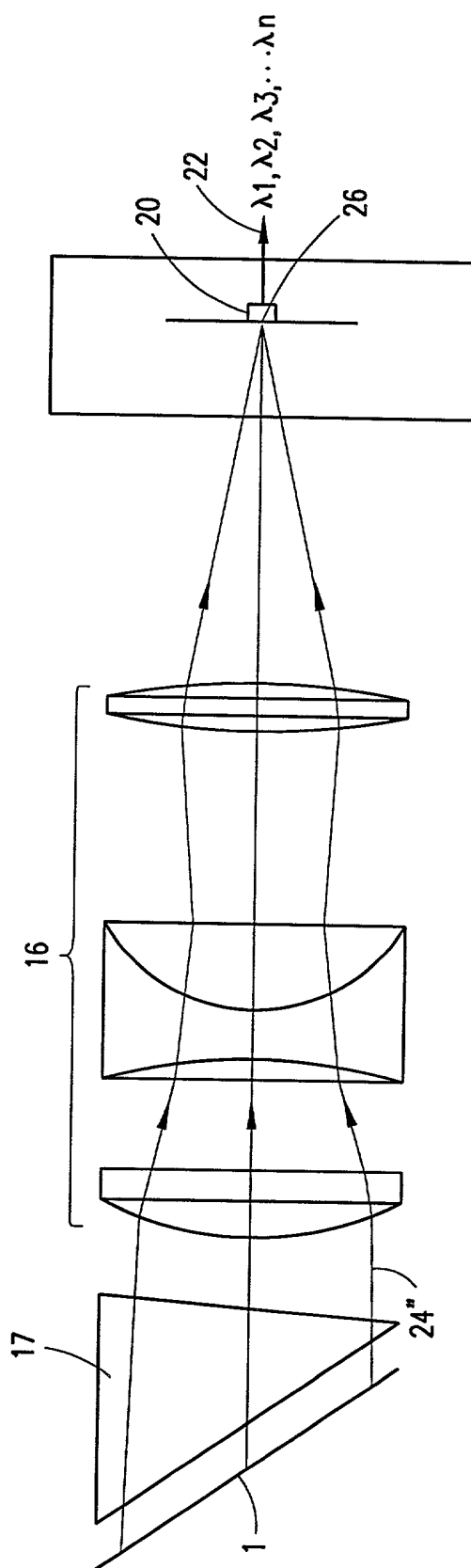


FIG. 9B



**FIG. 10A**



**FIG. 10B**

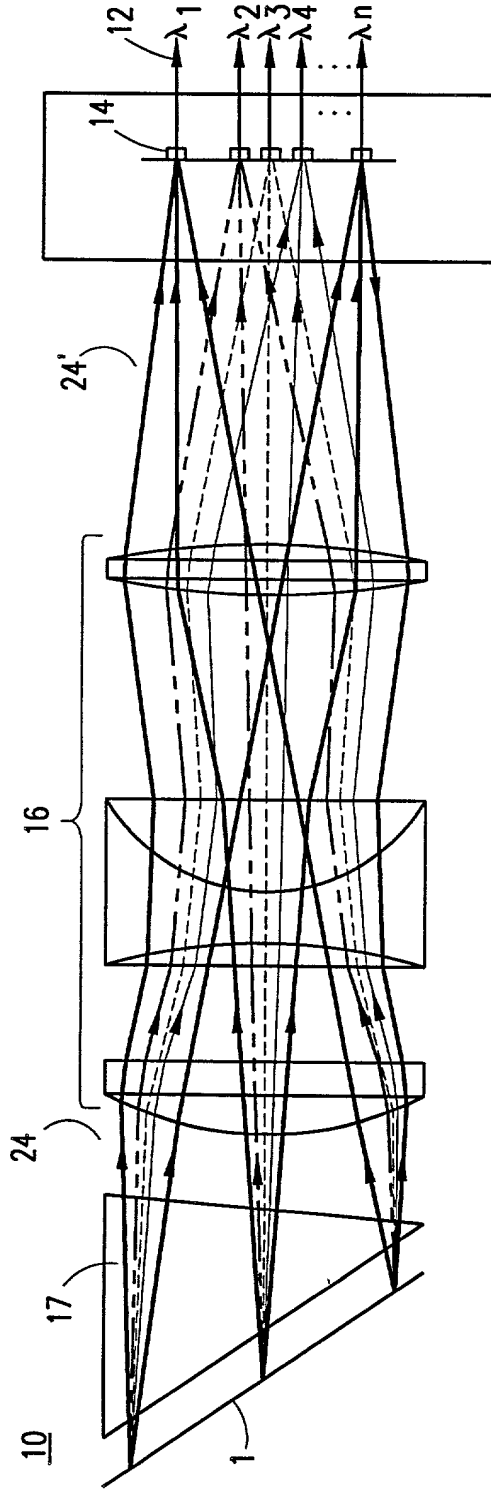


FIG. 10D

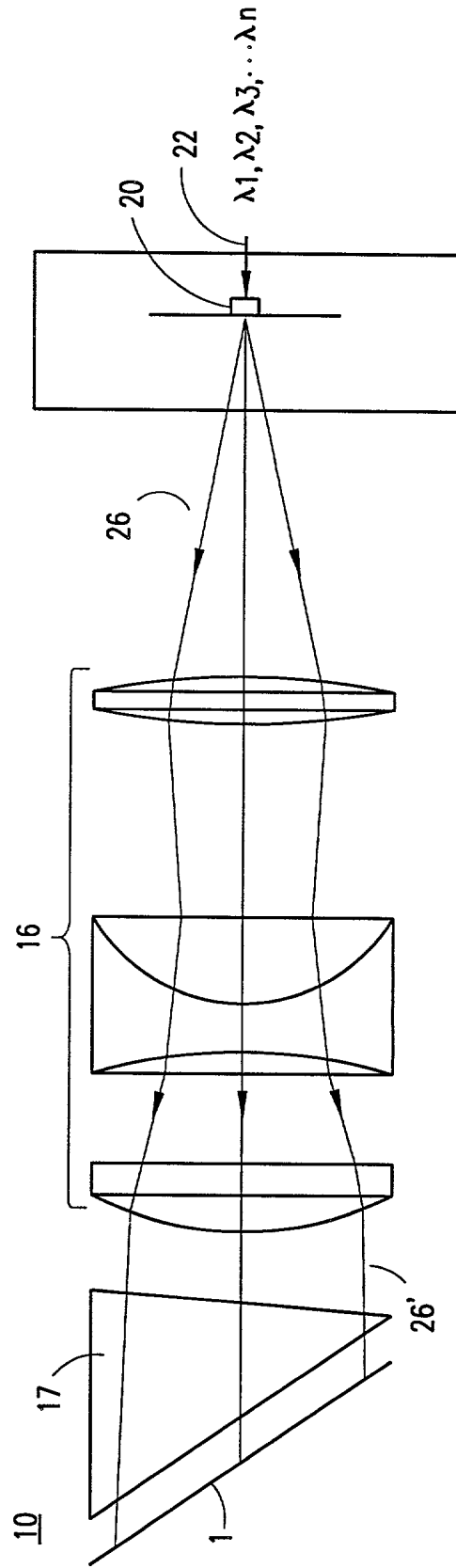
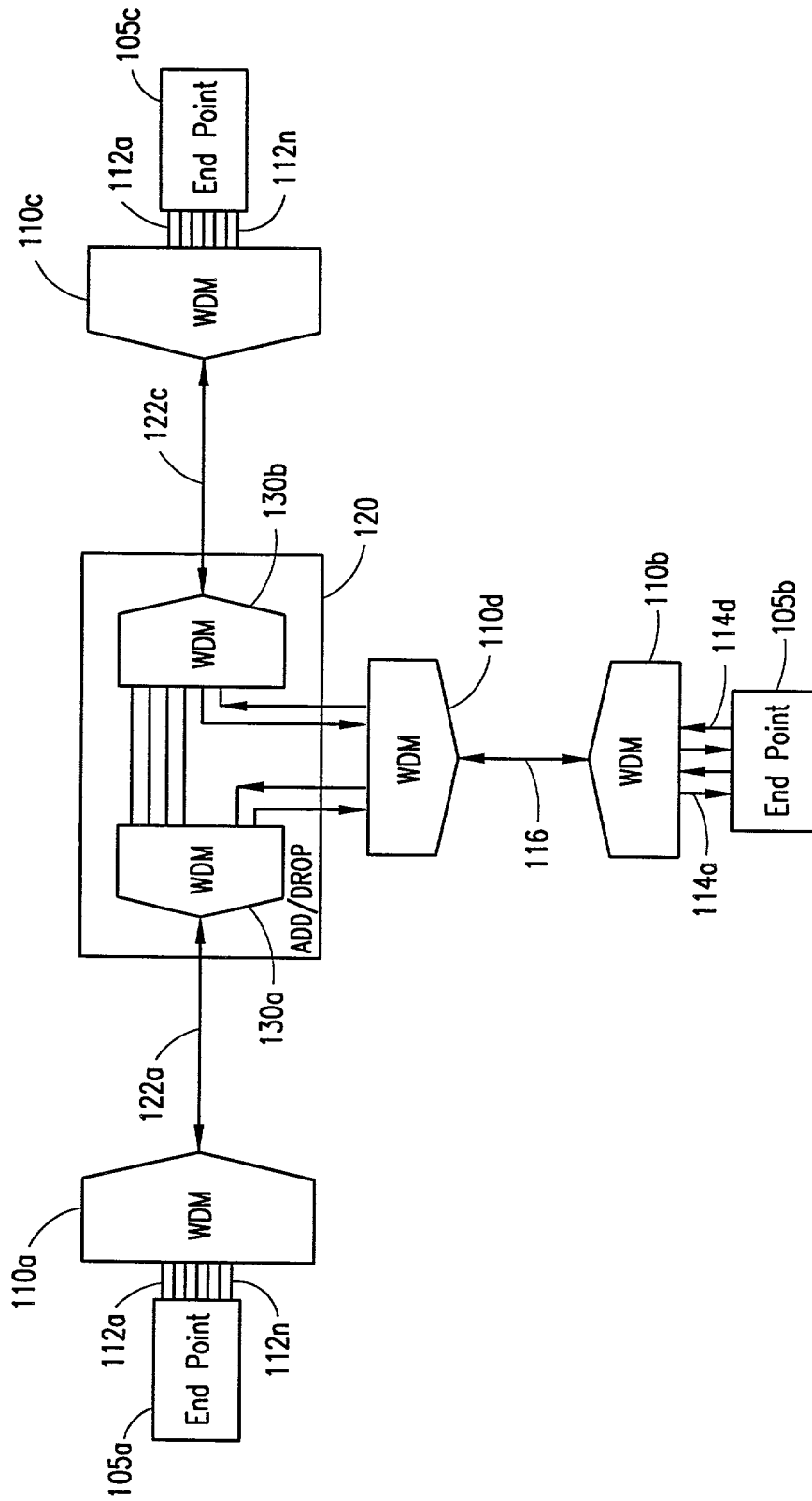


FIG. 10E

100*FIG. 11*

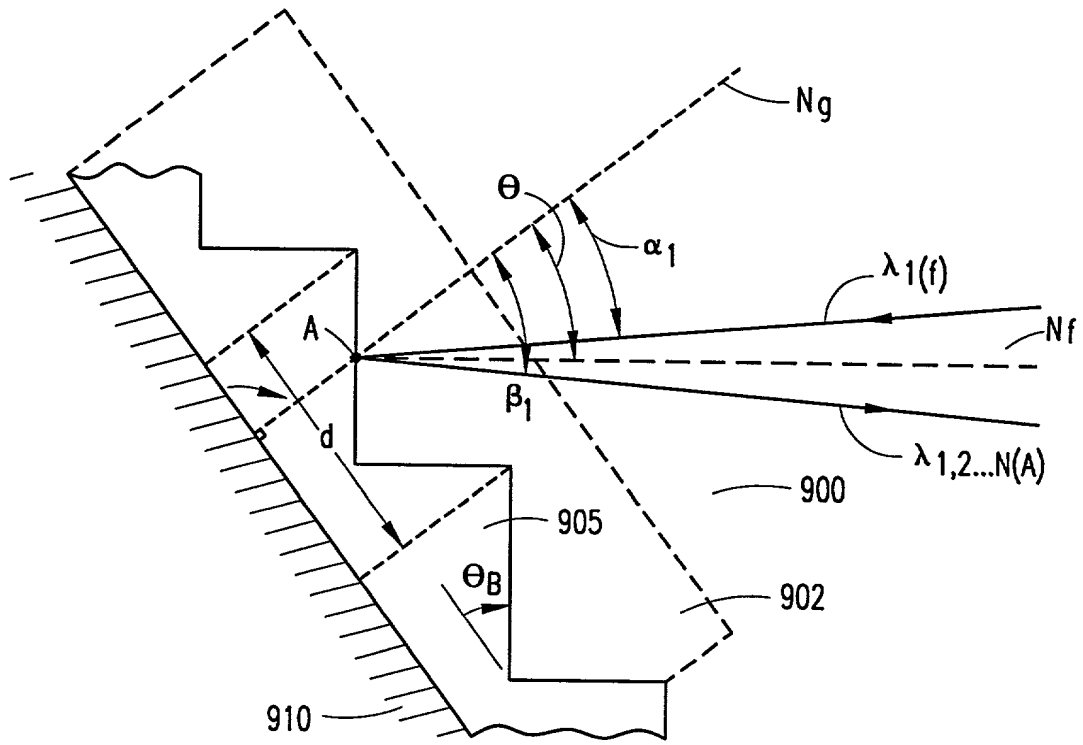


FIG. 12A

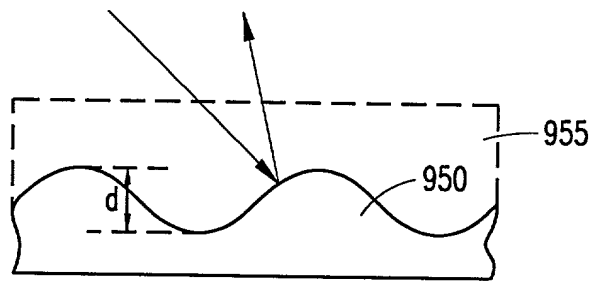


FIG. 12B

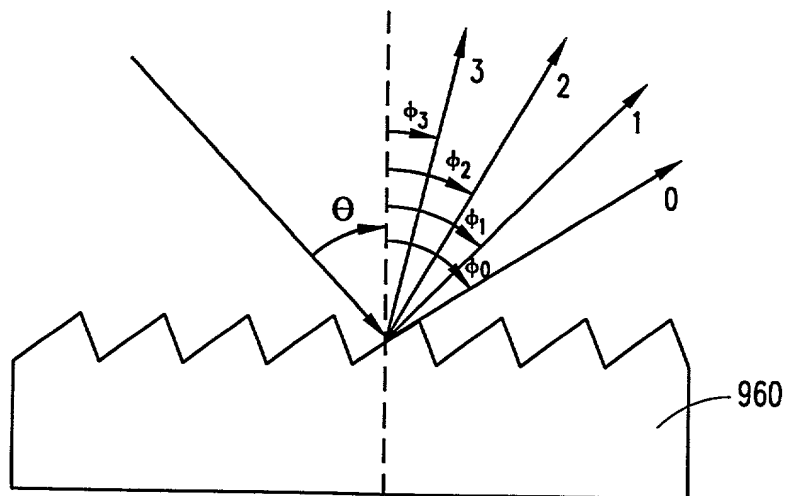


FIG. 12C



As a below named inventor, I hereby declare that:

I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **"DIFFRACTION GRATING FOR WAVELENGTH DIVISION MULTIPLEXING/DEMULTIPLEXING DEVICES"**, the specification of which:

(X only one) (a) X is attached hereto.

(b) \_\_\_\_\_ was filed as U.S. Patent Application No. \_\_\_\_\_ on \_\_\_\_\_, \_\_\_\_\_, and was amended on \_\_\_\_\_, \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims as amended by any amendment referred to above.

I hereby acknowledge the duty to disclose to the Office all information known to me to be material to the patentability of this application as defined in 37 CFR § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. § 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate filed by me or my assignee disclosing the subject matter claimed in this application and having a filing date (1) before that of the application on which my priority is claimed or, (2) if no priority is claimed, before the filing date of this application:

PRIOR FOREIGN PATENTS

Dallas2 734089 v 1, 34013.00028

listed below and PCT international applications listed above or below:

PRIOR U.S. OR PCT APPLICATIONS

Application No. (series code/serial no.)      Month/Day/Year Filed      Status(pending, abandoned, patented)

NONE

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below:

PROVISIONAL APPLICATIONS

<u>Application No. (series code/serial no.)</u>	<u>Month/Day/Year Filed</u>
60/208,478	June 2, 2000
60/208,482	June 2, 2000
60/208,477	June 2, 2000

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Ross Avenue, Suite 3200, Dallas, Texas 75202-2799, as my attorneys and/or agents, with full power of substitution and revocation, to prosecute this application, and any provisionals, continuations, continuations-in-part, divisionals, appeals, reissues, substitutions, re-examinations, and extensions thereof, and to transact all business in the United States Patent and Trademark Office connected therewith, to appoint any individuals under an associate power of attorney, and to file and prosecute any international patent application based thereon before any international authorities.

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(214) 855-4300

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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